The Status of Fertilizer Recommendation in Malawi:
Gaps, Challenges and Opportunities

James Mutegi, Vernon Kabambe, Shamie Zingore,
Rebbie Harawa and Lydia Wairegi

Soil Health Consortium of Malawi

The Status of Fertilizer Recommendation in Malawi: Gaps, Challenges and Opportunities

Authors:
James Mutegi[1], Vernon Kabambe[2], Shamie Zingore[1], Rebbie Harawa[3] and Lydia Wairegi[4]

[1]International Plant Nutrition Institute (IPNI), SSA Program c/o IFDC-East & Southern Africa Division, ICIPE Compound, Duduville- Kasarani, P.O. Box 30772-00100 Nairobi

[2]Lilongwe University of Agriculture and Natural Resources (LUANAR), Bunda College Campus, PO Box 219, Lillongwe, Malawi

[3]Alliance for a Green Revolution in Africa, West End Towers, 4th Floor, Kanjata Road, off Muthangari Drive, off Waiyaki Way, P.O. Box 66773-00800, Westlands, Kenya

[4] CAB International (CABI), Canary Bird
673 Limuru Road, Muthaiga P.O. Box 633-00621 Nairobi, Kenya

 Correct Citation: Mutegi J, Kabambe V, Zingore S, Harawa R and Wairegi L (2015) The Fertilizer Reccomendation Issues in Malawi: Gaps, Challenges, Opportunities and Guidelines: Soil Health Consortium of Malawi

Authors: James Mutegi[1], Vernon Kabambe[2], Shamie Zingore[1], Rebbie Harawa[3] and Lydia Wairegi[4]

[1]International Plant Nutrition Institute (IPNI), SSA Program c/o IFDC-East & Southern Africa Division, ICIPE Compound, Duduville- Kasarani, P.O. Box 30772-00100 Nairobi

[2]Lilongwe University of Agriculture and Natural Resources (LUANAR), Bunda College Campus, PO Box 219, Lillongwe, Malawi

[3]Alliance for a Green Revolution in Africa, West End Towers, 4th Floor, Kanjata Road, off Muthangari Drive, off Waiyaki Way, P.O. Box 66773-00800, Westlands, Kenya

[4] CAB International (CABI), Canary Bird
673 Limuru Road, Muthaiga P.O. Box 633-00621 Nairobi, Kenya

Design & Layout:
Conrad Mudibo, Ecomedia Limited (info@ecomedia.co.ke)

Contents

Chapter 1: Background

There is an urgent need to increase agricultural production in sub-Saharan Africa (SSA) with a main focus on increasing the use of improved seeds and fertilizers by smallholder farmers. More importantly, an integrated approach to soil fertility management (ISFM) that combines the use of improved crop varieties with mineral fertilizers and organic resources, and good management is required to increase crop productivity while reversing soil fertility depletion. Nutrients are more effectively used when the right source of nutrients are applied at the right rate, time and place, in what is termed as the 4 Rights (4Rs) of nutrient management. In addition, other agronomic practices including land preparation, timing of planting and weeding and plant spacing should also be correctly implemented.

For most countries in SSA, a major challenge to effective nutrient management is the lack of site-specific fertilizer recommendations that are appropriate for the socio-economic conditions of the farmers. Fertilizer recommendations are mostly generalized for all soil types and ecological conditions, irrespective of the huge biophysical, ecological and socioeconomic variability at different scales. This often results in a mismatch between nutrient application and actual requirements, translating into suboptimal agronomic and economic efficiency, low crop yields, food insecurity and wasted human, capital and financial investment. The government of Malawi has made significant strides in addressing food security challenges by providing farmers with improved seed varieties and fertilizer under the Fertilizer Input Subsidy Program (FISP). The investment in seed and fertilizer under the subsidy program has, however, not been not been supported with effective crop-specific and location-specific fertilizer recommendations. Although the subsidy program in Malawi has resulted in substantial increases in food production, the agronomic efficiency of N (defined as unit of grain produced per unit of fertilizer N applied) of only 14 kg grain/kg N applied (National Statistical Office Malawi Government, 2008) has been poor and is less than half the efficiency that can readily be achieved with good management. Some of the gaps identified for increasing fertilizer use efficiency and the subsidy impacts on crop productivity include improving input distribution logistics to ensure timely delivery of the inputs and improving targeting of beneficiary households and supplying the correct fertilizers for different soil fertility conditions (Dorward and Chirwa, 2011). As a background to the AGRA Workshop on Fertilizer Recommendations in Malawi, August 27-28, 2014, this report provides an overview of the status and gaps for the development and dissemination of effective soil fertility management recommendation for Malawi.

Characteristic and role of agriculture in Malawi

Malawi has one of the highest rural population densities in sub-Saharan Africa; at 2.3 rural people per hectare of agricultural land compared to 0.4 people for the sub-continent as a whole (Benin et al., 2008). The climate is sub-tropical with two distinct seasons, the rainy season from November to April and the dry season from May to October. Annual rainfall in Malawi ranges from 700 to 1800 mm. The precipitation pattern is unimodal, with 4-6 months of rain followed by 6-8 dry months. High variability of precipitation both within and between growing seasons is typical of southern Africa and makes rainfed agriculture a risky proposition. The mean annual minimum and maximum temperatures for Malawi range from 12 to 32 °C. On the climate basis, the country is divided into eight agroecological conditions typically referred to as the Agricultural Development Divisions (ADD) (Chinsinga, 2012).

Agriculture is the mainstay of Malawi's economy. In 2007, the share of agriculture of GDP was 34%. Around one-third of all households in Malawi are rural small-scale farmers, and two-thirds of these farmers reside in the three larger central and southern regions. Malawi's agricultural sector is characterized by a dualistic structure: a low input/low productivity smallholder sector and high input/high productivity estate sector. The smallholder sub-sector comprises a very large number of small-scale farmers growing mainly food crops for their own consumption but they also grow some cash crops such as coffee, tobacco, macadamia and cotton. The estate sector comprises a much smaller number of large-scale farmers, producing almost entirely for the export market. The main food crop is maize, which accounts for nearly 90% of the cultivated land, supplemented by sorghum, millet, pulses, rice, root crops, vegetables and fruits. Malawi consumes over 150 kg maize per capita per year, which constitutes greater than two-thirds of the caloric consumption - the largest per capita maize consumption in the world (Smale and Heisey, 1997). The main estate-grown crops are tobacco, coffee, tea and sugar. Table 1 presents a summary of land allocation and yields of most common crops in Malawi.

The crop yields of most common crops have however stagnated at less than 50% of the actual attainable yields, leading to declining per-capita food production as the population grows. For example, while the attainable yields for maize varieties that are used are 6 to 10 t/ha, on average smallholder farmers produce only about 2 t/ha. The large yield gaps have been associated with declining soil fertility due to low and inappropriate fertilizer application in the crop lands. The government of Malawi has made notable achievements to support smallholder farmers to increase fertilizer use through fertilizer subsidy programs, but major gaps remain in the development and dissemination of appropriate fertilizer recommendations that take into account the variability in soil fertility and socioeconomic characteristics. Indeed a number of studies in southern Africa have highlighted the need for site-specific nutrient management recommendations that are appropriate for the large variability in soil fertility conditions at different spatial scales (Zingore et al., 2007).

Table 1: *Land allocation and production of common food crops in Malawi*

	Smallholder farms-5 year (2007-11) averages			Estate farms-5 year (2007-11) averages			
Crop	**Area (ha)**	**Total production (tons)**	**Average yield (tons/ha)**	**Area (ha)**	**Total production (tons)**	**Average yield (tons/ ha)**	**Cumulative production (tons)**
Maize	1,628,306	3,224,070	2.0	56,929	182,497	3.21	3,406,567
Sorghum	78,456	61,533	0.8	0	0	0	61,533
Rice	60,884	116,914	1.9	0	0	0	116,914
Millet	44,891	29,736	0.7	0	0	0	29,736
Wheat	1,610	2,765	1.7	25	52	0.82	2,817
Pulses	636,691	462,145	0.7	13,097	10,698	0.81	472,843
Groundnuts	281,560	281,302	1.0	14,354	17,467	1.21	298,769
Cassava	188,909	3,817,081	20.1	2,431	52,675	21.60	3,869,755
S Potatoes	169,777	2,716,523	15.9	2,601	50,654	19.35	2,767,176

Source: IFDC, 2013.

Landscape characteristics of smallholder farms in Malawi

Malawi's topography is characterized by extremely diverse physical features. It is divided into four major physiographic zones:

- The highlands of Mulanje, Zomba and Dedza in the southern part of the country;
- The plateau of the central and northern regions;
- The rift valley escarpment;
- The rift valley plains along the lakeshores of Lake Malawi, the Upper Shire and Lower Shire Valleys.

According to FAO, the soils of Malawi have been grouped into 28 classes, predominated by three major soil types:

- The Eutric Leptosols, known as Lithosols, which occur in most areas of the country;
- The Chromic Luvisols, generally known as Latosols, which are the red-yellow soils of the Lilongwe plain and some parts of southern region;
- The Haplic Lixisols, which are the alluvial soils of lacustrine and river-line plains, the Vertisols of the lower shire valley and Phalombe plain and the Mopanosols in the Liwonde and Balaka areas.

Chapter 2: Soil fertility characterization in Malawi

It remains a considerable challenge to characterize soil fertility of smallholder farming systems in Malawi because the extremes in topography confounded with small field sizes and diversity in crop and nutrient management practices, which have led to complex soil fertility variability within short distances (Snapp and Benson, 1995). Analysis of soil fertility at appropriate scales provides a foundation for understanding the requirements for fertilizer and organic inputs. There are very few studies that have been conducted for large-scale characterization of Malawi soils using comparable protocols. Most studies that have been conducted to characterize agricultural soils in Malawi have been limited to the plot level. The varying laboratory analytical methods used across the studies make it difficult to compare soil fertility information across sites and studies difficult. One of the studies that conducted a detailed soil fertility analysis to allow multi-location assessment of key soil parameters was by Snapp (1998). The study had three objectives which were: i) to characterize soil nutrient status (P, Zn, K, Ca), soil texture and pH in key agricultural regions of Central, Southern and Northern Malawi, ii) to quantify the relationship of organic C to other soil characteristics, and iii) to develop a spatial understanding of soil characteristics. To achieve these objectives, Snapp (1998) characterized the soils of Malawi in the North (represented by Karonga and Mzuzu ADD), in the Centre (represented by Lilongwe and Kasungu) and in the South (represented by Blantyre).

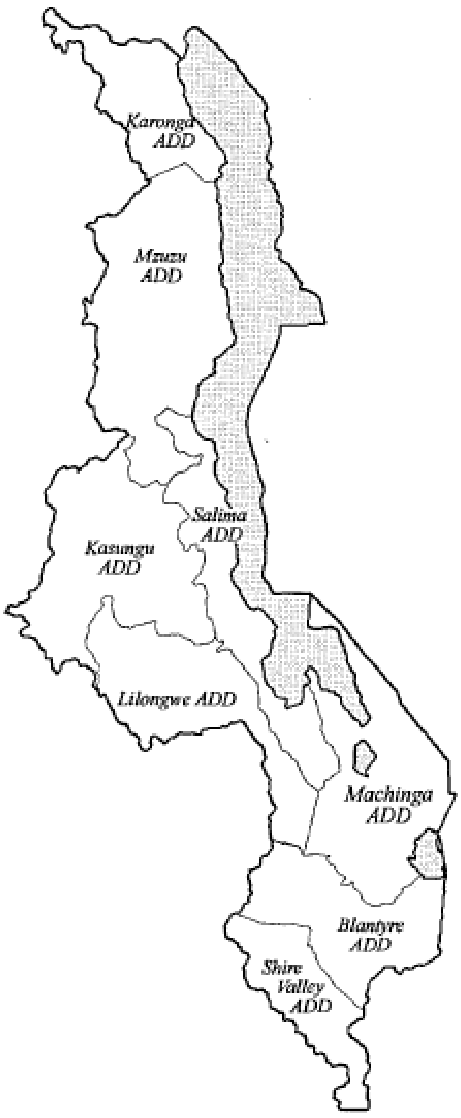


Figure 1: *Map of Malawi showing the boundaries of the 8 Agricultural Divisions (ADD) or the agro ecological zones. Shaded area is Lake Malawi (Source: Snapp et al 1998)*

All locations where soil samples were collected were geo-referenced using grid overlays on maps. A subset of 1,130 soil samples from the Mzuzu, Karonga, Kasungu, Lilongwe, and Blantyre agricultural development divisions (ADD) were identified as reliable. The first two districts represent the Northern, the second two districts the Central, and the last district the Southern regions of Malawi (Figure 1). Nutrient status, soil texture, and slope at each site sampled was used to develop descriptive statistics for soil samples from these districts which represents about 60% of the land area of Malawi. Descriptive statistics (mean, mode, and range) from the soil sample database were analyzed based on location, for the five ADDs and for 88 natural regions in Malawi. The natural regions were defined by agro-ecological groups as defined through physiography, climate, and land suitability classes by the Lands Evaluation Project

(Venema, 1990). The mean values and standard deviation for soil characteristics for each natural region was evaluated to detect locations which were above or below the mean for the country.

2.1 Key soil characteristics

Table 2 presents the results obtained for the five ADDs. The results show a variability of more than 100% for most soil parameters across the agricultural development divisions implying that no single fertilizer recommendation can work for all the regions. For between 10 and 30% of the ADDs, the soil organic carbon (SOC) was lower than the critical level required for proper functioning of the soil. Maintenance and management of soil organic carbon is central to sustaining soil fertility on smallholder farms (Swift and Woomer 1993, Woomer et al. 1994). A decline in SOC is associated with decline in organic matter input into the soil and accelerated SOC decomposition due to intensive tillage. Soil organic matter (SOM) helps to retain nutrients in the soil and make them available to plants in small amounts over a long period of time as SOM mineralizes. In addition, SOM increases soil flora and fauna (associated with soil aggregation, improved infiltration of water and reduced soil erosion), complexes toxic Al and Mn ions (leading to better rooting), increases the buffering capacity on low-activity clay soils, and increases water holding capacity (Woomer et al. 1994). As SOM is one of the most important parameters in driving the physical, chemical and biological characteristics of the soil, management practices that build SOM are required in many areas to maintain SOC above the critical values that support optimal crop response to fertilizer application.

Although average pH values were mostly above critical levels, the pH was critically low in most acidic soils, indicating a need for targeted lime application. Other than in Kasungu ADD, where over 99% of the farms had a pH that was higher than the critical limit of 5.2, in other ADDs, between 13 and 35% of the farms had lower pH than the critical limit, the most affected being Lilongwe (35% being lower than critical) and Blantyre ADD (20% of farms lower than critical).

Most of the previous fertilizer recommendations in Malawi are based on addressing the N and P deficiencies. The soil analysis results show that K could be deficient in up to 25% of the farms in some regions including Mzuzu. It is key to note that even in regions such as Blantyre where K deficiencies were observed in only 1% of the farms, the farm to farm and within farm variability is very high. Among the elements that were analyzed for, P was the most limiting nutrient. The intra- and inter-farm variability for P was also very high, as indicated by the minimum values of less than 1 mg kg^{-1} and the maximum values greater than 80 mg kg^{-1}.

A study by Weil and Mughogho (2000) that covered an area of more than 200 km^2 in Balaka, Salima, Lilongwe and Mzuzu provided insights into S deficiencies in major maize growing regions in Southern, Central and Northern Malawi. Using a combination of foliar sample analysis in farmers' field and multi-location experiments, the study showed that although N and P were the most limiting nutrients, deficiencies of S were widespread and occurred in at least 80% of fields surveyed.

Table 2: *Descriptive statistics of soil fertility indicators in the five Agricultural Development Divisions (ADD) in Malawi. Critical soil test values used; organic C =0.8%; pH =5.2; Zn = 0.5 mg kg^{-1}, Ca = 0.2 cmolc kg^{-1}, K =0.2 cmolc kg^{-1}, P = 13 mg kg^{-1} (Source: Snapp, 1998)*

Characteristic	%>critical	Mean	Minimum	Maximum
Organic C%				
Mzuzu	72.4	1.2	0.2	3.0
Karonga	80.1	1.3	0.4	3.3
Lilongwe	90.6	1.6	0.4	3.3
Kasunga	91.8	1.7	0.3	4.6
Blantyre	77.0	1.2	0.3	2.9
pH				
Mzuzu	87.1	5.7	4.4	7.7
Karonga	87.9	6.2	4.0	8.3
Lilongwe	66.1	5.4	4.7	6.8
Kasunga	99.2	5.9	4.3	7.2
Blantyre	78.0	5.9	5.1	6.9
Zn (mg kg^{-1})				
Mzuzu	92.5	1.4	0.2	5.2
Karonga	94.0	1.8	0.0	6.4
Lilongwe	97.1	1.4	0.2	6.0
Kasunga	91.9	1.5	0.1	5.7
Blantyre	90.0	1.7	0.0	9.6
Ca (cmol$_c$ kg^{-1})				
Mzuzu	98.2	2.3	0.1	5.5
Karonga	99.5	3.1	0.1	6.2
Lilongwe	100	4.1	0.8	21
Kasunga	100.0	1.9	0.2	6.0
Blantyre	99	3.0	0.2	9.5
K (cmol$_c$ kg^{-1})				
Mzuzu	74.1	0.5	0.1	5.1
Karonga	88.5	0.7	0.1	2.5
Lilongwe	88.5	0.4	0.1	1.1
Kasunga	83.6	0.5	0.1	1.5
Blantyre	99	1.1	0.0	13.0
P (mg kg^{-1})				
Mzuzu	57.9	21.7	1.0	184.1
Karonga	58.8	30.1	0.1	163.0
Lilongwe	64.3	31.3	0.6	130.2
Kasunga	59.3	24.2	0.1	81.0
Blantyre	77	45.5	0.9	119.0

Chapter 3: Assessment of the gaps of current fertilizer recommendations

Malawi is only 118,000 km^2 in area, yet it has a very diverse agro-ecology, with 55 natural regions (Benson, 1997). As indicated earlier, the varied terrain and soil types make blanket fertilizer recommendations impractical. The government of Malawi has over the last three decades succeeded to improve fertilizer access by smallholder farmers, while national and international research organizations have conducted research activities aimed at enhancing fertilizer use efficiency in Malawi. The fertilizer subsidy program implemented by the Malawi Government has led to increased fertilizer supplies from14,237 metric tons in 2005 to 216,553 metric tons in 2009 (IFDC 2013). This translated to increasing fertilizer use intensity from less than 20 kg ha^{-1} in 2000 to 43 kg ha^{-1} in 2009 (IFDC 2013). Although the average crop yields in Malawi have increased in tandem with increase in use of fertilizers, the economic and agronomic efficiency of using fertilizer is stuck at less than 50% of actual potential. Current fertilizer application is based on blanket recommendations that focus on N and P, and to a less extent S, although there are indications for the need to address soil acidity and deficiency of other nutrients to match the wide variability of soil types and nutrient levels across Malawi. Fertilizer trials conducted more recently show that K, S and micronutrients such as Zn and Bo, and pH are crucial for enhancing crop response to N and P fertilizers. In addition to these issues, a lack of information about correct application rates, timings, and the use of the correct products for different crops remain major challenges.

Similar to the situation in many other countries in SSA, fertilizer recommendations in Malawi are very broad, with limited attention to resource variability and a cash-constrained farming environment (Snapp and Benson, 1995; Kumwenda et al., 1997). Nitrogen (N) has been shown to be generally the most limiting nutrient. Phosphorus (P), sulfur (S), and zinc (Zn) responses have also been shown for specific crops and regions in Malawi (Brown and Young, 1966; Chilimba, 1996; Snapp et al.1998). An updated analysis of soil nutrient status in Malawi would facilitate development of targeted recommendations. Improving fertilizer recommendations or developing more effective site-specific nutrient management recommendations are crucial for not only increasing yields, but also improving the nutritional status of the food produced to address the problems of malnutrition that are common in Malawi.

The current nation-wide fertilizer recommendations for maize, millet, sorghum and rice are presented in Table 3. Fertilizer rates are adjustable, depending on site characteristics. These recommendations fail to consider the diversity in soil types, farmer resources or yield goals. Yet this is the prevailing popular fertilizer recommendation used by extension staff to support farmers across Malawi. There is scope to increase N fertilizer efficiency by providing appropriate micronutrients on a location-specific basis (Wendt et al., 1994). In this study by Wendt et al. (1994), supplementation by S, Zn, B, and K increased maize yields by 40% over the standard N-P recommendation alone. There is also evidence that fertilizer efficiency in smallholder cropping systems can be significantly increased by adding fertilizer in combination with high-quality organic matter (Ladd and Amato, 1985; Snapp, 1995). High quality organic nutrient resources (with narrow C/ N ratio and a low percentage of lignin) provide readily available N and nutrients to the soil ecosystem, and they build soil organic matter over the long term. The use of high quality organic resources will increase soil microbial activity and nutrient cycling and reduce nutrient loss from leaching and denitrification (De Ruiter et al. 1993).

Table 3: *Current fertilizer recommendations (kg ha^{-1})*

Maize	Millet	Sorghum	Rainfed Rice	Irrigated Rice
92 kg N, 42 kg P_2O_5, 8 kg S	46 kg N, 42 kg P_2O_5 and 8 kg S	46 kg N, 42 kg P_2O_5 and 8 kg S	83 kg N, 25 kg P_2O_5, 4.8 kg S	83 kg N, 25 kg P_2O_5, 4.8 kg S

Chapter 4: Previous efforts to develop site-specific fertilizer recommendations for Malawi

The efforts to develop appropriate fertilizer recommendations in Malawi have evolved over a long period of time. Initial efforts led to the development of blanket recommendation for the whole country, and this was followed by programs to develop more site-specific fertilizer recommendations. This section reviews the fertilizer recommendations that have been developed over the past four decades in Malawi.

4.1 The Blanket Fertilizer Recommendation of 1980

The blanket fertilizer recommendations for Maize in 1980s were pegged at 87 kg of Di-ammonium Phosphate (DAP) fertilizer and 175 kg of urea fertilizer per hectare of hybrid maize (Snapp et al., 1998). This provided the crop with 96 kg of nitrogen and 40 kg of P_2O_5 per ha. The blanket recommendation was based on practical considerations for extension to communicate uniform messages rather than based on site-specific needs or the socio-economic circumstances of poorly resourced farmers. The recommendation ignored differences between soils and was highly incompatible with smallholders' resources (Kumwenda et al., 1996). The effectiveness of this blanket recommendation was low due to a number of reasons:

i. Yields of 3 t/ha that farmers could achieve with application of fertilizer at the recommended rate were below optimal target yields of 5-7 t/ha.

   The recommended fertilizer was uneconomic as more than 40% of the farmers who applied fertilizer at recommended rate failed to recover the cost of fertilizer application.

ii. The recommendations did not take care of other limiting nutrients other than N and P.

iii. The blanket recommendation covered only nitrogen and phosphorus, resulting in unbalanced nutrient application. For many areas of the country the recommended N and P rates were too high for maize production. Moreover, the need for S was not addressed, despite widespread deficiencies of S in many soils in Malawi.

4.2 Maize Fertilizer Recommendation Work in the 1990s

Using data from 500 trials carried out in 296 sites over 11 years (1975/1976-1981/1982, 1986/1987, 1991/1992-1993/1994), spatial variability of response of maize to nitrogen fertilizer was explored (Benson, 1996). The medium textured uplands had the largest response to nitrogen compared to other zones (Table 4). For light textured uplands, the linear equation was $y=1725+15.6N$ in poor rainfall years and $y=1747+20.4N$ in years of good rainfall, suggesting that moisture stress limited crop response to nitrogen more than leaching.

Table 4: *Nitrogen response functions by recommendation zone*

Zone	Linear response function	Quadratic response function
Lower Shire Valley	Y=2790+0.6N	$Y=2657+6.2N-0.028N^2$
Lakeshore	Y=2164+13.6N	$Y=2001+20.4N-0.035N^2$
Medium-textured upland	Y=2133+20.9N	$Y= 2042+24.8N-0.020N^2$
Light-textured upland	Y=1749+18.9N	$Y=1571+26.1N-0.037N^2$

(*Source: Benson, 1996*)

Maize fertilizer recommendation trials were carried out by the Maize Productivity Taskforce between 1996 and 1999. The members of the taskforce were drawn from the Ministry of Agriculture, Bunda College of Agriculture, DARS - Chitedze Agricultural Research Station and the Ministry of Finance. All the eight ADDs (extension planning area) were subdivided into extension jurisdiction areas abbreviated as EPA (Extension Planning Aarea) or larger agricultural districts termed RDP (Rural Development Projects) (Benson, 1997). These recommendation trials were intended to update and improve the 1980 blanket fertilizer recommendation of 87 kg of DAP and 175 kg of urea per ha of hybrid maize which did not take care of diversity of soils in Malawi and flexibility in application rates to optimize economic returns to investment in fertilizer.

These recommendations were developed principally using data collected from the nationwide Fertilizer Verification Trial of 1995/96.

A total of 1920 fertilizer verification trials (Table 5) were carried out in 153 Extension Planning Areas (EPAs) (Kumwenda, 1998). The study concluded that based on maize-fertilizer price ratios, the current fertilizer recommendations (92 kg N, 40 kg P_2O_5/ha) were uneconomical – not applying fertilizer was the only economical treatment in 86% of the EPAs.

Table 5: *Fertilizer levels tested in the verification trial at 1920 locations in 1995/96*

Treatment	Element and rate of application				Provisional recommendation
	Nitrogen	Phosphorus	Sulphur	Fertilizer package	
1	96	40	0	DAP & Urea	Current recommendation
2	0	0	0	0	Lower Shire
3	35	0	0	Urea	Lakeshore
4	35	10	2	23:21:0+4S & Urea	Lakeshore
5	65	21	4	23:21:0+4S & Urea	Medium textured soils in mid-altitude area
6	92	21	4	23:21:0+4S & Urea	Light textured soils in mid-altitude area

(*Source: Kumwenda, 1998*)

This recommendation was based on a decision tree considerate of the driving objectives for production for home consumption and the driving objectives for production for the market. Details of this decision tree are highlighted below.

4.3 Fertilizer recommendations decision tree

The decision tree diagram in Figure 2 shows how fertilizer recommendation was determined according to location and production objective. In contrast to the blanket recommendation, these area-specific recommendations provide two optional rates of fertilizer application. Decision on the rate of fertilizer application depends on whether the farmer is producing maize for market or home consumption. In order to use the basic area-specific fertilizer recommendations, there are two factors that must be considered:

1) The EPA in which the farmer is growing the maize. The area-specific recommendations apply to Extension Planning Areas or to larger agricultural extension districts – Rural Development Projects (RDP) or Agricultural Development Divisions (ADD). Consequently, the farmer needs to know in which EPA he or she is farming. Location is important when considering fertilizer use based on the general weather and soil conditions that the farmer should expect.

2) *The production aim of the farmer.* The production aim of the farmer is either for home consumption and use or for sale at the market. The farmer places a different value on the maize depending on the intended use of the maize. If producing for the market, the applicable value for the maize is the producer price that the farmer will receive in the market. However, if the farmer is producing for home consumption, the significantly higher consumer maize price is used. This is because the value of the maize that the farmer produce is less than the maize purchased in the market at the consumer maize price and transported back home. As a result, higher rates of fertilizer were recommended for maize produced for home consumption.

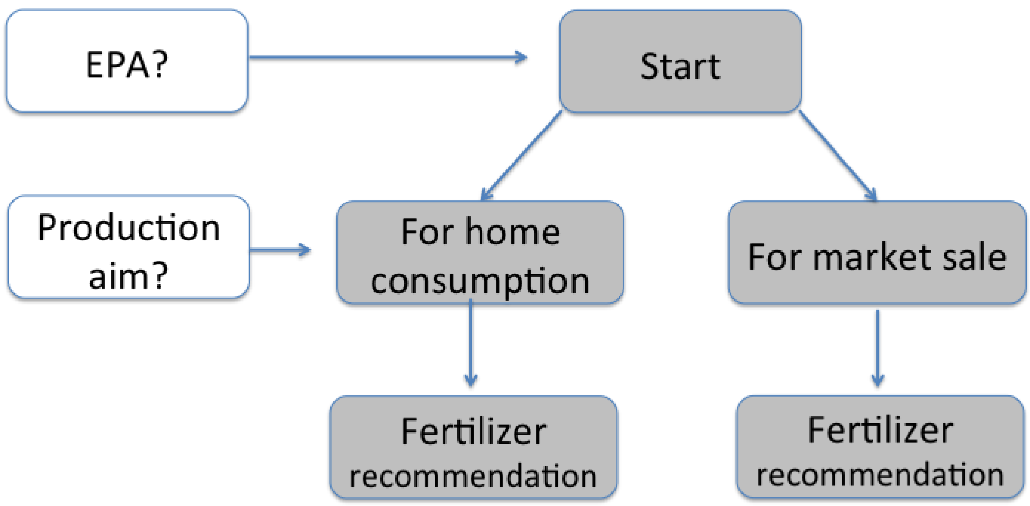


Figure 2*: Decision tree underlying fertilizer recommendation for hybrid maize*

This analysis therefore considered both the yields and economic returns. The recommendations that were developed based on these considerations for different agro-ecologies and extension units are presented in Table 6 and Figure 3.

Despite the range of recommendations proposed, 92:21:0+4S was adopted by almost all smallholder farmers because most grow maize for household consumption, and there was inadequate training of the extension staff and farmers on the new area specific fertilizer recommendations, and lack of sensitization campaigns to popularize the area specific fertilizer recommendations (Makumba, Personal communication).

From 1998/99 to 2000/01, Sasakawa Global 2000 led a project that set up 5426 maize management training plots in Malawi. The demonstrated technologies included spacing ridges at 75 cm instead of the traditional spacing of 90-110 cm, spacing maize at 25 cm, one seed per hole along the ridge instead of 3 seeds at 90-100cm (to increase plant population from 37,000 to 54,000 plants per ha), and a blanket fertilizer recommendation rate of 92 kg N and 21 kg P_2O_5 per ha.

Unlike most studies that based fertilizer recommendations on optimizing crop responses, a crude analysis by IFDC quantified amounts of fertilizer that would be required to increase crop production by 6% based on nutrient removal and fertilizer use efficiency for N, P and K (IFDC, 2013). The report suggested increasing maize production by 1,152,000 tonnes required additional nutrient removal of 16,320 tonnes of N, 7130 tonnes of P_2O_5, 4130 tonnes of K_2O. The report further suggested that in order to obtain projected increase in production for the targeted crops, there was need to double fertilizer consumption. Such a crude analysis may provide a stopgap recommendation for use to support fertilizer policy guidelines, but has limited relevance to improving fertilizer recommendations.

Table 6: *Area-specific fertilizer recommendations for maize by RDP and EPA*

		For Home Consumption		For Market Sale	
ADD	**RDP & EPA**	**Light-textured**	**Medium-textured**	**Light-textured**	**Medium-textured**
Karonga	Chitipa RDP	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Karonga RDP	35:10:0+2S	35:10:0+2S	nil	nil
	Misuku Division - SCA	35:10:0+2S	35:10:0+2S	nil	nil
Mzuzu	Rumphi / North Mzimba RDP				
	Mpherembe & Bolero	92:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Bwengu, Zombwe, & Muhuju	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Central Mzimba RDP				
	All except Eswazini	92:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Eswazini	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	South Mzimba RDP				
	Mbawa	92:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Champhira, Emfeni, & Khosolo SCA	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Nkhata Bay RDP				
	Mpamba, Chitheka, & Chikwina SCA	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Nkhata Bay & Chintheche	69:21:0+4S	69:21:0+4S	35:10:0+2S	35:10:0+2S
	Rumphi Division - SCA	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S

		For Home Consumption		For Market Sale	
Kasungu	Kasungu RDP	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Mchinji RDP	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Dowa West RDP	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Dowa East RDP	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Ntchisi RDP	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
Lilongwe	Lilongwe West RDP	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Lilongwe East RDP	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Thiwi-Lifidzi RDP	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Dedza Hills RDP	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Ntcheu RDP				
	Njolomole & Tsangano	69:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Kandeu, Nsipe, & Manjawira	35:10:0+2S	69:21:0+4S	nil	35:10:0+2S
Salima	Salima RDP	69:21:0+4S	69:21:0+4S	35:10:0+2S	35:10:0+2S
	Nkhotakota RDP				
	Nkhunga & Linga	69:21:0+4S	69:21:0+4S	35:10:0+2S	35:10:0+2S
	Zidyana & Mwansambo	92:21:0+4S	92:21:0+4S	35:10:0+2S	35:10:0+2S
	Bwanje RDP	92:21:0+4S	92:21:0+4S	35:10:0+2S	35:10:0+2S
Machinga	Mangochi RDP				
	Mbwadzulu, Nasenga, & Mthiramanja	92:21:0+4S	92:21:0+4S	35:10:0+2S	35:10:0+2S
	Maiwa, Lungwena, & Mpilipili	69:21:0+4S	69:21:0+4S	35:10:0+2S	35:10:0+2S
	Namwera RDP	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Balaka RDP	35:10:0+2S	69:21:0+4S	nil	35:10:0+2S
	Kawinga RDP	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Zomba RDP				
	Mtubwi, Chingale, Nsondole, Mpokwa, & Ngwelero	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Thondwe, Malosa, & Dzaone	92:21:0+4S	92:21:0+4S	nil	35:10:0+2S
Blantyre	Blantyre-Shire Highlands RDP				
	Lirangwe	35:10:0+2S	69:21:0+4S	nil	35:10:0+2S
	Ntonda, Mombezi, & Thumbwe	92:21:0+4S	92:21:0+4S	nil	35:10:0+2S
	Matapwata, Thyolo North, & Masambanjati	69:21:0+4S	69:21:0+4S	nil	35:10:0+2S
	Mulanje RDP	35:10:0+2S	69:21:0+4S	nil	35:10:0+2S
	Phalombe RDP	35:10:0+2S	69:21:0+4S	nil	35:10:0+2S
	Mwanza RDP	35:10:0+2S	69:21:0+4S	nil	35:10:0+2S
Shire Valley	Chikwawa & Nsanje RDPs	35:10:0+2S	35:10:0+2S	nil	nil

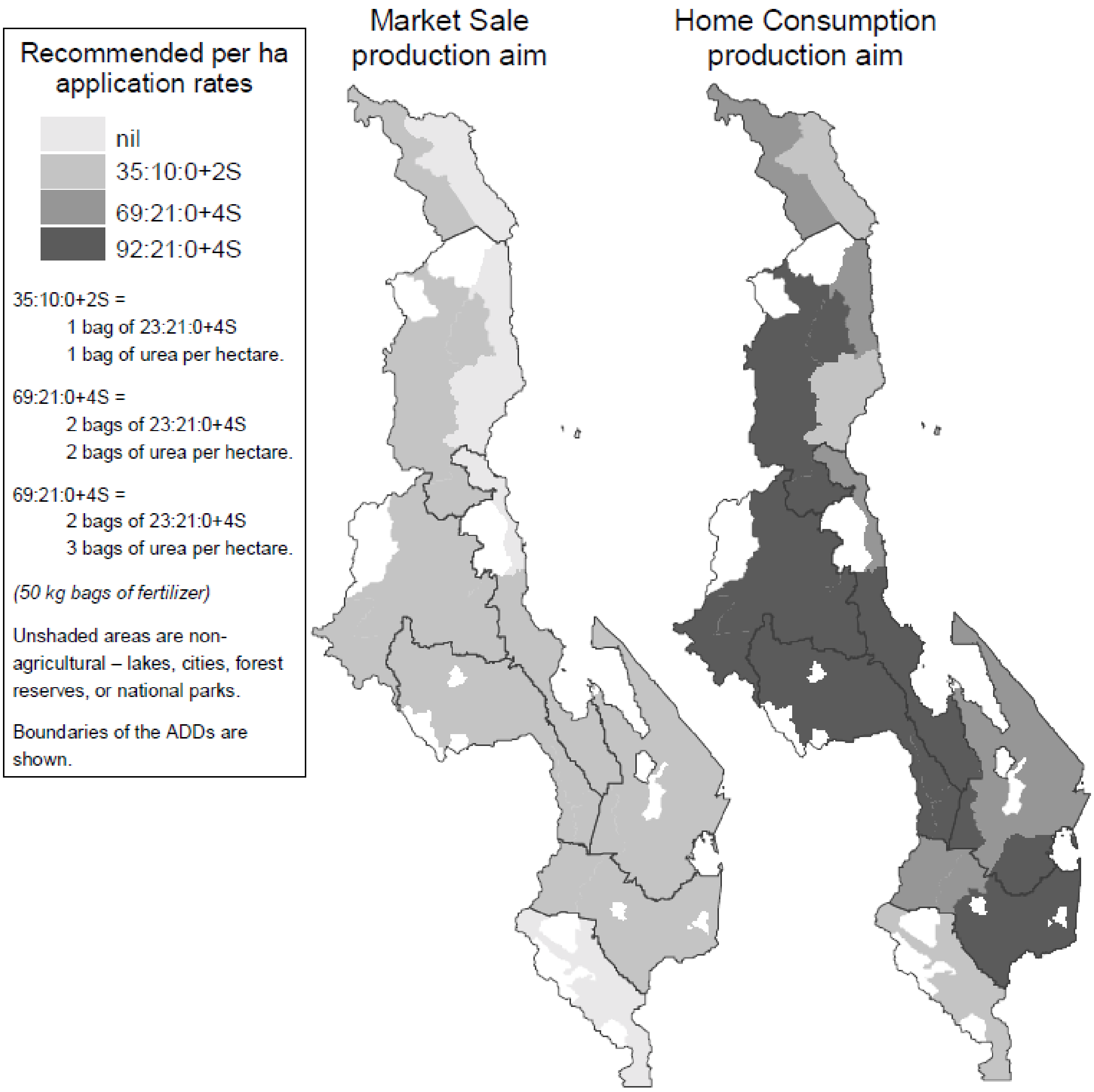


Figure 3: *Distribution of fertilizer recommendations for hybrid maize on a map (Source: Benson, 1999)*

4.4 Fertilizer recommendation with leguminous interventions

It is widely accepted that most farmers in SSA cannot afford sufficient inorganic fertilizers to meet the optimal crop requirements. In fact, the government of Malawi is promoting integration of legumes into the agricultural production systems to cut the cost of fertilization. Furthermore, organic resources in addition to improving soil fertility improve other soil health parameters like soil physical properties (soil water retention, soil structure etc.) and microbial diversity. As production of sufficient organic resources to meet the nutrient requirements for the crops in not feasible, most studies propose a judicious mix of both organic and inorganic materials within the framework of ISFM, thus balancing the chemical, physical and biological characteristics of the soil and improving the crop production environment (Vanlauwe et al., 2007). A comprehensive study was conducted by the Maize productivity taskforce (Gilbert et al., 2002) to evaluate the possible fertilizer recommendation scenarios with various promising leguminous cropping systems 1998/1999 in the 8 ADD. The trial treatments were as shown in table 7:

Table 7*: Treatments used in legume-fertilizer best fit trials*

		1998/99	1999/2000
ID	**System**	**Description**	**Description**
1.GL	Grain legume rotation	Either Magoye soybean or CG7 groundnut	Hybrid maize fertilized at the rate of 35:10:0+2S ($N:P_2O_5:K_2O+S$)
2.MP	Mucuna rotations	Mucuna pruriens	Hybrid maize fertilized at rates of 35:10:0+2S ($N:P_2O5:K_2O+S$)
3.MZ/PP	Maize/pigeonpea intercrop	Maize and ICP 9145 pigeonpea intercropped	Hybrid maize fertilized at rates of 35:10:0+2S ($N:P_2O_5:K_2O+S$)
4.MZ+F	Fertilized maize	Hybrid maize fertilized at either 35:10:0+2S or 69:21:0+4S ($N:P_2O_5:K_2O+S$)	Hybrid maize fertilized at rates of 35:10:0+2S ($N:P_2O_5:K_2O+S$)
5.MZ	Unfertilized maize	Hybrid maize seed without fertilizer	Hybrid maize seed without fertilizer
6.Local	Local control	No treatment imposed; maize yield data collected from farmer's own field adjacent to research plots	No treatment imposed ; maize yield data collected from farmers field adjacent to research plots

(*Source: Gilbert et. al., 2002*)

4.5 Impact of legumes on crop yields

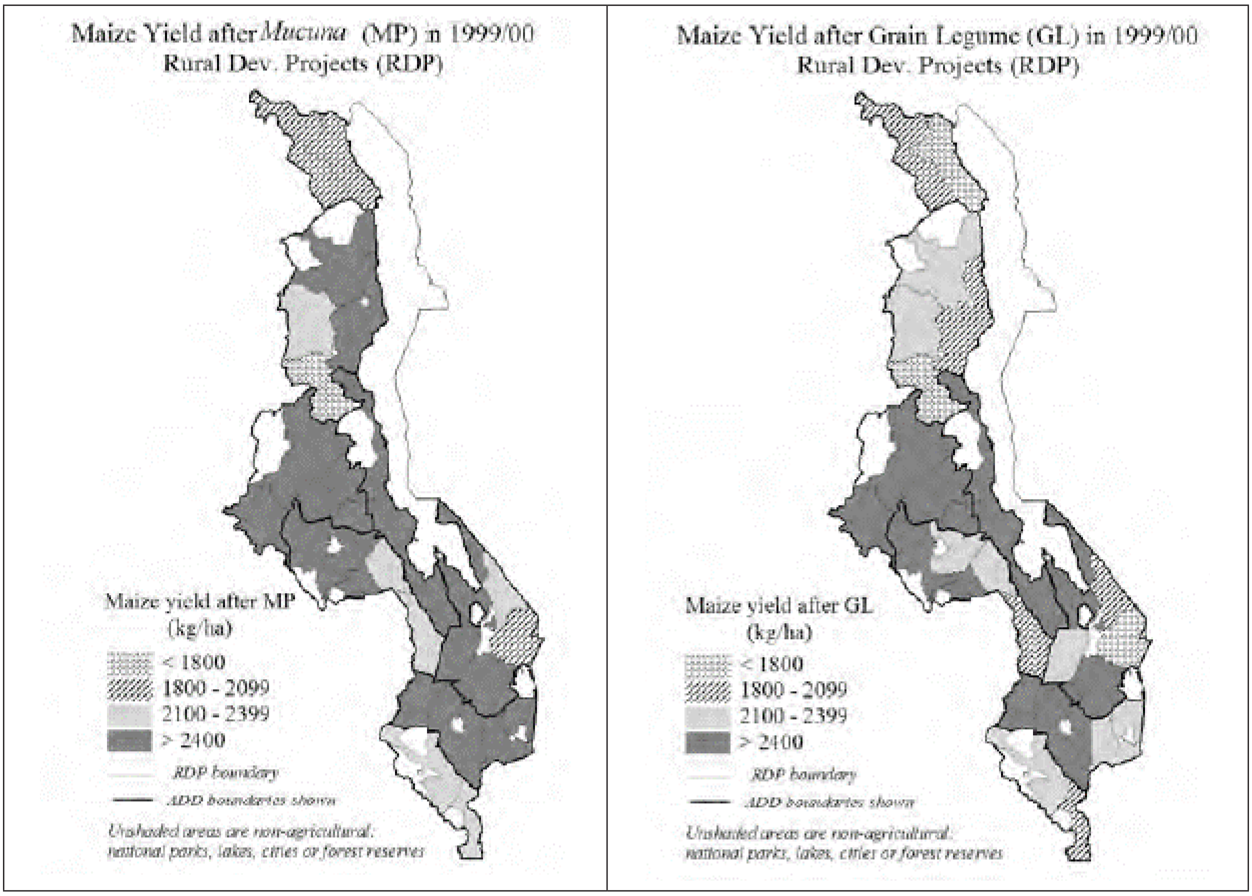
The impact of these treatments on crop yields was evaluated and mapped (Figure 4). In summary:

For year 1 (1998/1999)

- The national average legume yield were Mucuna 1.7 tons ha^{-1}, soybean (1.0 tons ha^{-1}), and pigeon pea (0.4 tons ha^{-1})
- The maize yield from maize-pigeon pea intercrop (1.2 tons ha-1) was similar to sole unfertilized maize (1.2 tons ha^{-1}) indicating that pigeon pea was a bonus crop. As expected, pigeon pea yields were highest in southern Malawi
- Fertilized hybrid maize had significantly higher average yields (2.5 tons ha^{-1}) and calories produced (9090 Mcal/ha) than all other treatments in every ADD. Fertilized maize remains a powerful option for improving household food security in Malawi

For year 2 (1999/2000)

- Maize following mucuna had highest average grain yield (2.5 tons ha^{-1}) across the 8 ADD followed by maize following grain legume rotations (2.3 tons ha^{-1}). Maize following maize-pigeon pea intercrop was equivalent to maize from fertilized plots at about 2.0 tons ha^{-1}
- Karonga ADD, Lilongwe ADD, Blantyre ADD and Salima ADD showed the best yield responses to legume rotation



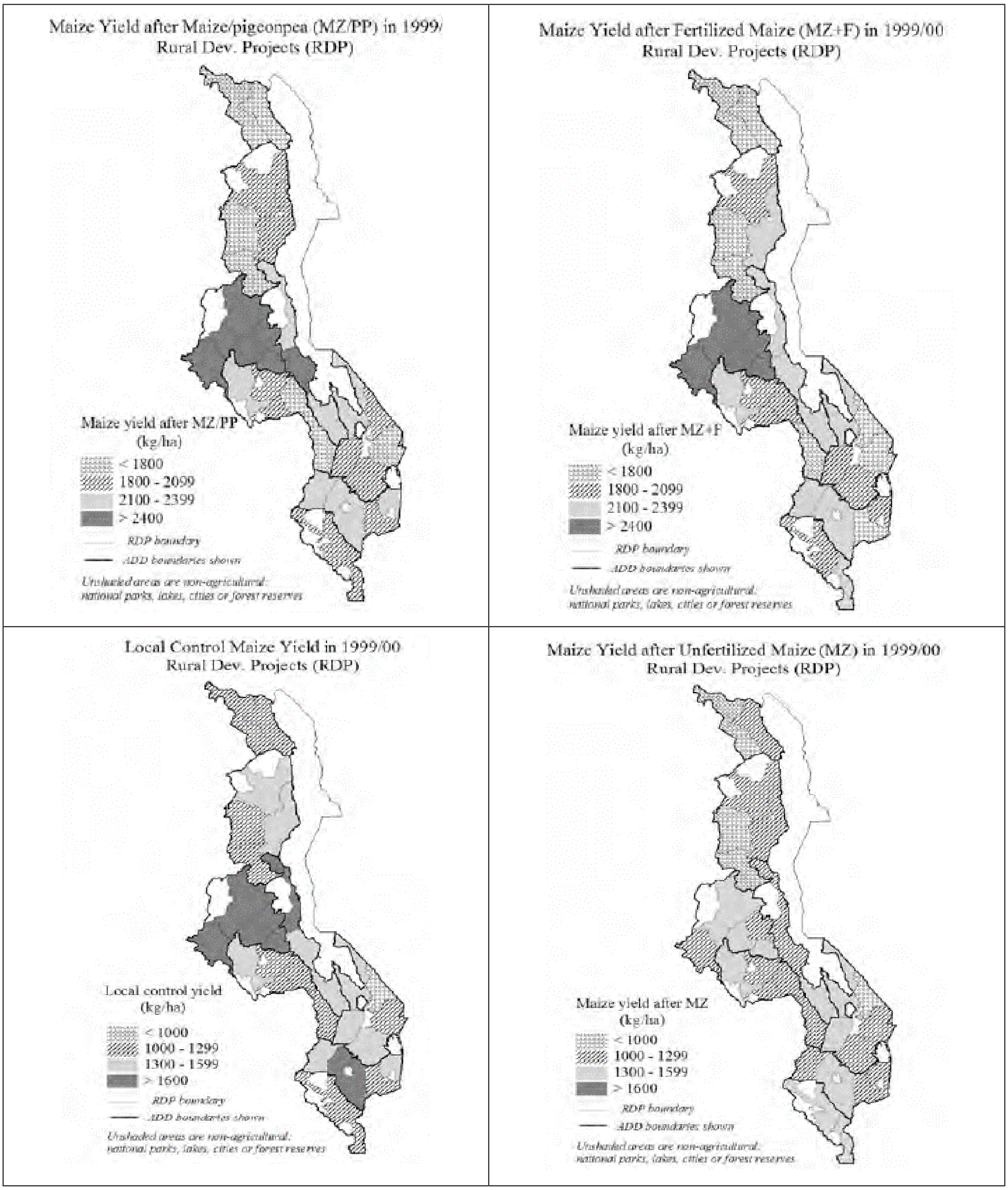


Figure 4: *Crop yield levels in different Malawi locations following legume interventions (Source: Gilbert et. al., 2002)*

Using the crop yields and market values, the cost-benefit calculations were conducted and used to produce the area specific fertilizer recommendations by RDP for differing fertilizer: maize price ratio and legume price scenarios. The residual was calculated using the formula:

The final recommendation was based on a calculated residual. Residual income is income in excess of opportunity cost. Residual=NB-(TCV*MARR) where: NB is the net benefits, TCV is Total variable cost and MARR is the minimum acceptable rate of returns. Detailed calculation procedures are presented in Gilbert et al. (2002). On the basis of crop yields, Figure 5 shows the site specific recommendations for legumes and fertilizers.

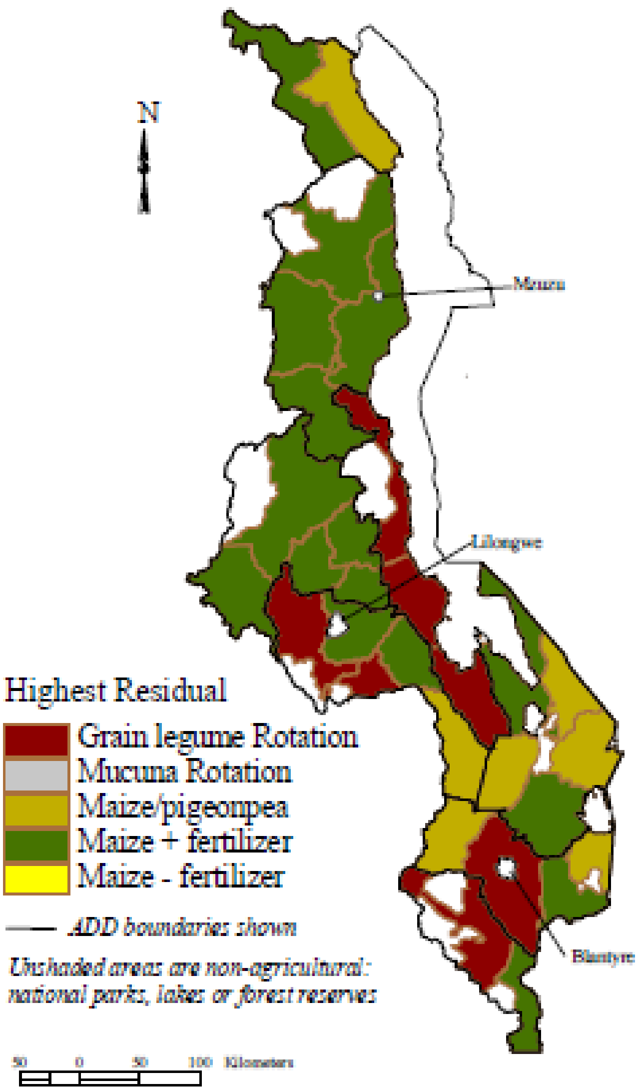
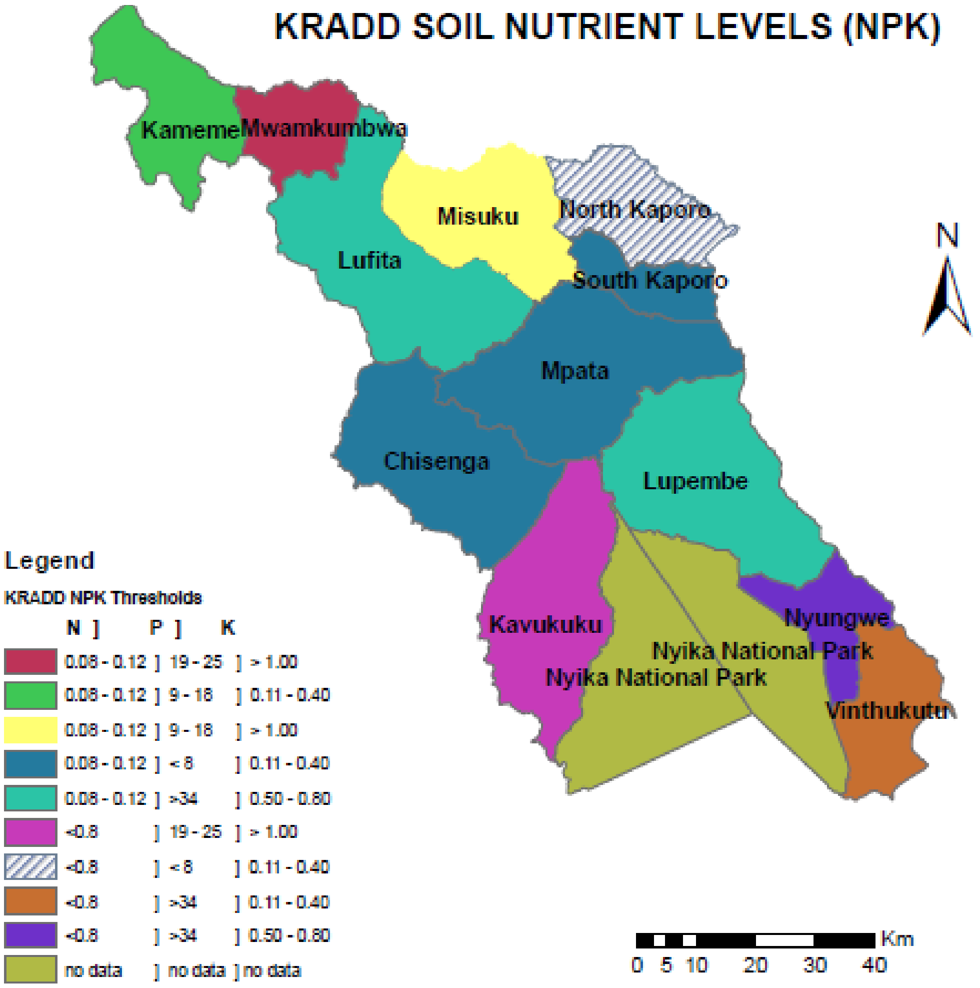


Figure 5: *Site specific recommendations for legumes and fertilizers (Source: Gilbert et al., 2002)*

4.6 Recent attempts to map soils and develop fertilizer recommendations for Malawi

A team from the Department of Agricultural Research Service (DARS) recently developed soil fertility maps and produced fertilizer recommendations (Chilimba and Nkosi., 2014) through the support of the ministry of agriculture and food services and LUANAR with part of funding from the Malawi Soil Health Consortium. Some of soil data used was collected from literature and project reports of earlier studies that were funded by the Rockefeller, FAO, PROSCARP and AGRA at different periods from 1990s to 2010. In cases where studies had used different extractants for soil extraction, Chilimba and Nkosi (2014) used the mathematical relationships derived by Chilimba et al. (1999) to convert the results from various extraction methods to similar data ranges. As a result of combining results from many studies and complimenting with additional mapping coupled with ground trothing, this study produced maps of soil fertility status of various ADDs that address deficiencies of other nutrients besides N, P and S. This section presents those results. The first batch of maps cover the macronutrients (N, P, K), the second batch covers pH and Zn status. The maps further present the soil nutrient thresholds and fertilizer recommendations for each EPA. This fertilizer recommendation group notes that although some EPAs have no Zn and sulphur soil data, maize responses to sulphur and Zn applications have been wide spread in the country and would recommend wide spread application of S and Zn containing fertilizers.



Nutrient Thresholds

Nitrogen %	Rating	N kg ha-1	P (µg g-1)	Rating	P kg ha-1	K cmol/kg	Rating	K kg ha-1
< 0.08	Very low	92	< 8	Very low	40.00	< 0.05	Very low	60.00
0.08 - 0.12	Low	92.00	9 - 18	Low	20.00	0.06 - 0.10	Low	30.00
0.12 - 0.20	Medium	46.00	19 - 25	Medium	10.00	0.11 - 0.40	Medium	10.00
0.20 - 0.30	High	23.00	25 - 33	High	0.00	0.50 - 0.80	High	0.00
> 0.30	Very high	0.00	>34	Very high	0.00	> 1.00	Very high	0.00

***Figure 6**: Map of Karonga Agricultural Development Division (KRADD) showing NPK nutrient status with application recommendations (Source: Chilimba and Nkosi, 2014)*

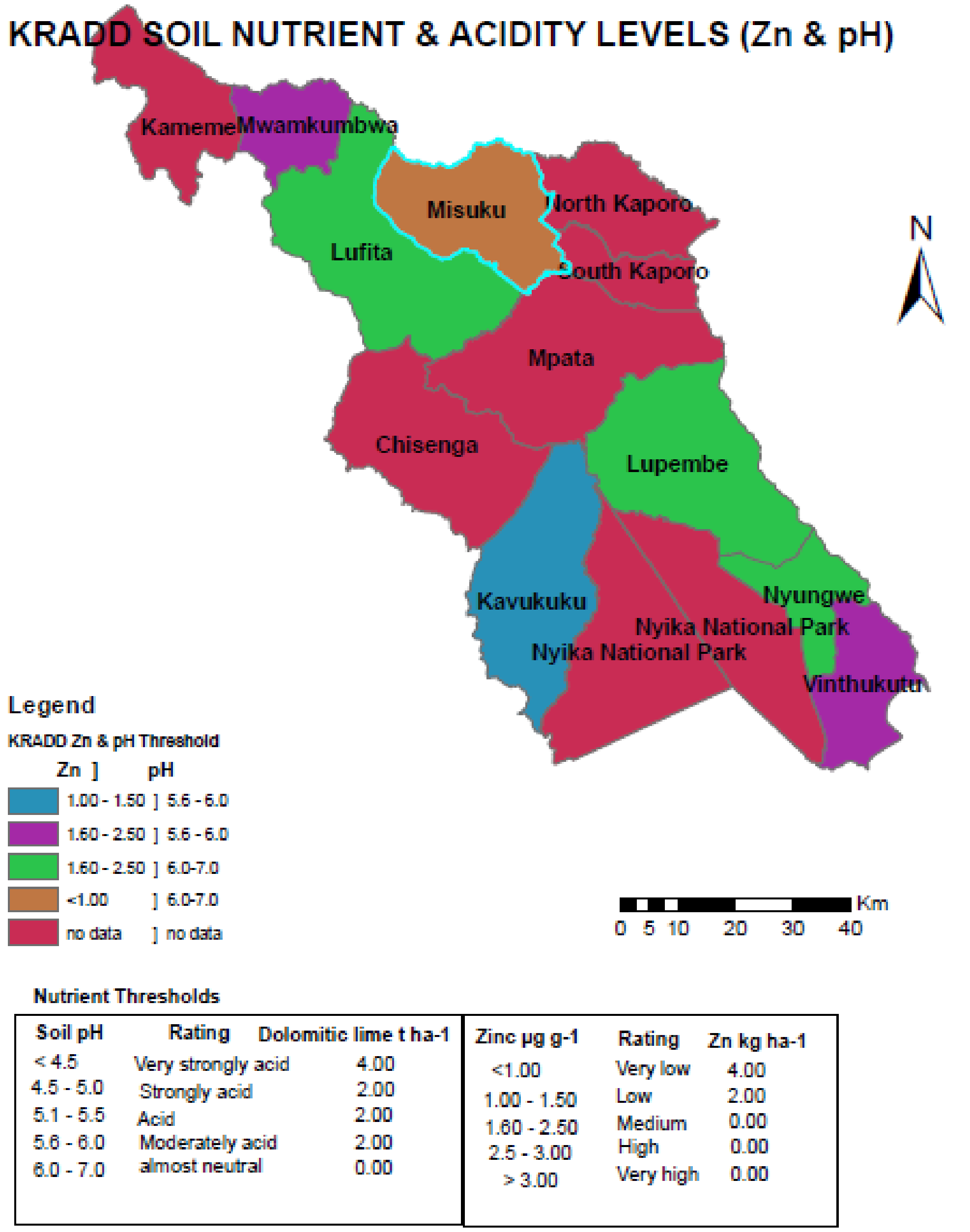


Figure 7: *Map of Karonga Agricultural Development Division (KRADD) showing soil pH and Zn nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

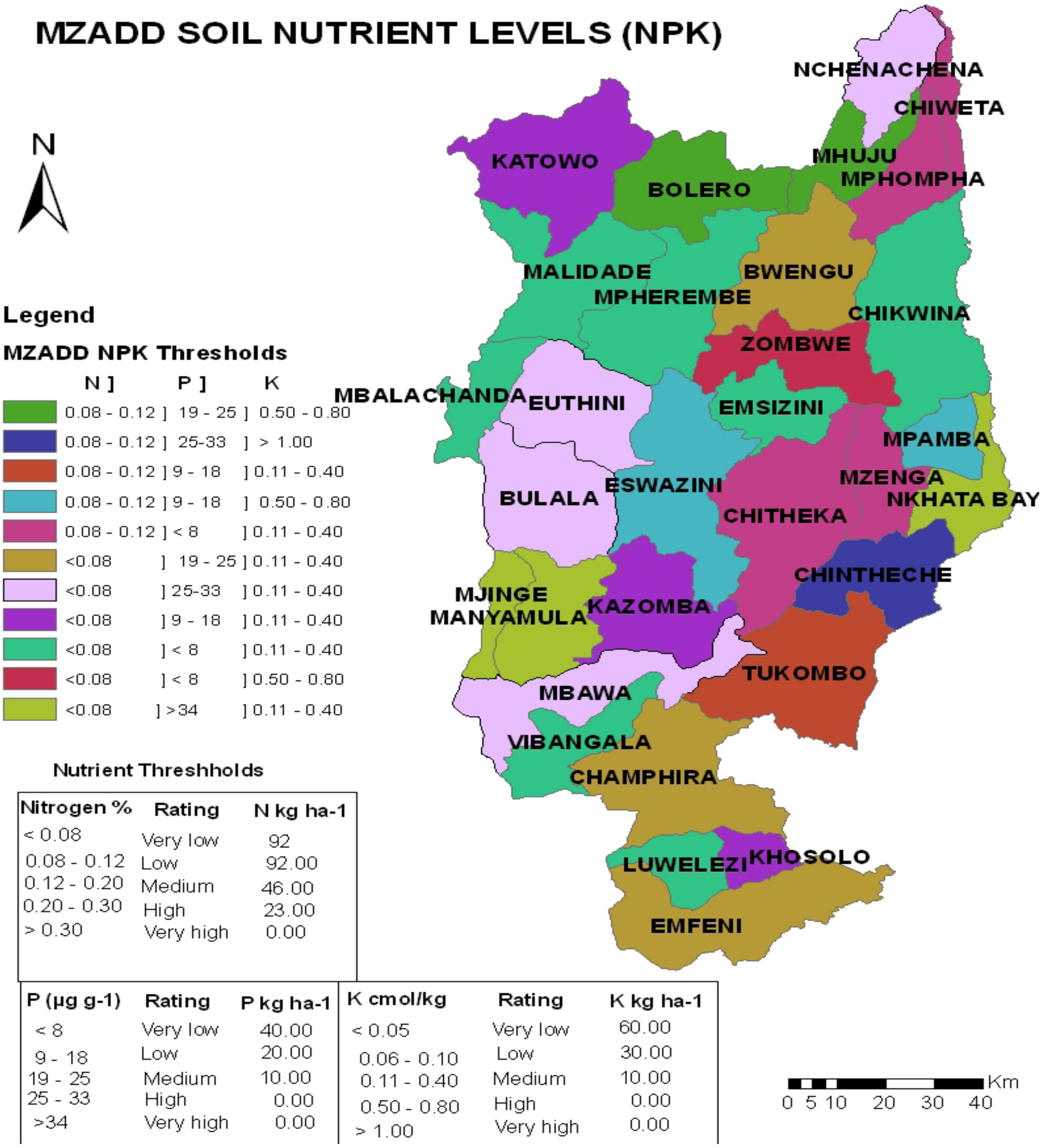
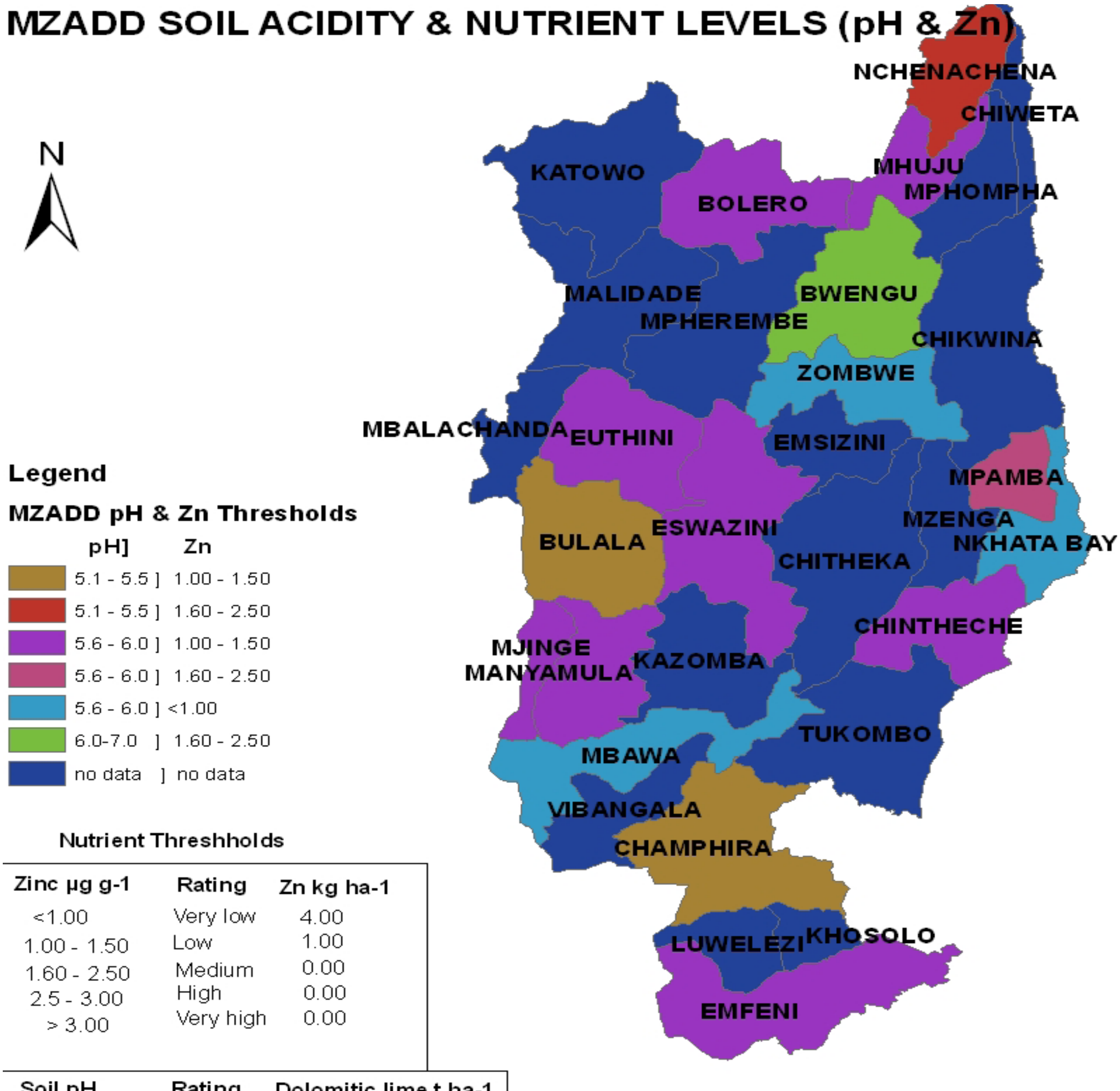


Figure 8: *Map of Mzuzu Agricultural Development Division (MZADD) showing NPK nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*



Nutrient Threshholds

Zinc µg g-1	Rating	Zn kg ha-1
<1.00	Very low	4.00
1.00 - 1.50	Low	1.00
1.60 - 2.50	Medium	0.00
2.5 - 3.00	High	0.00
> 3.00	Very high	0.00

Soil pH	Rating	Dolomitic lime t ha-1
< 4.5	Very strongly acid	4.00
4.5 - 5.0	Strongly acid	2.00
5.1 - 5.5	Acid	2.00
5.6 - 6.0	Moderately acid	2.00
6.0 - 7.0	almost neutral	0.00

Figure 9: *Map of Mzuzu Agricultural Development Division (MZADD) showing soil pH and Zn nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

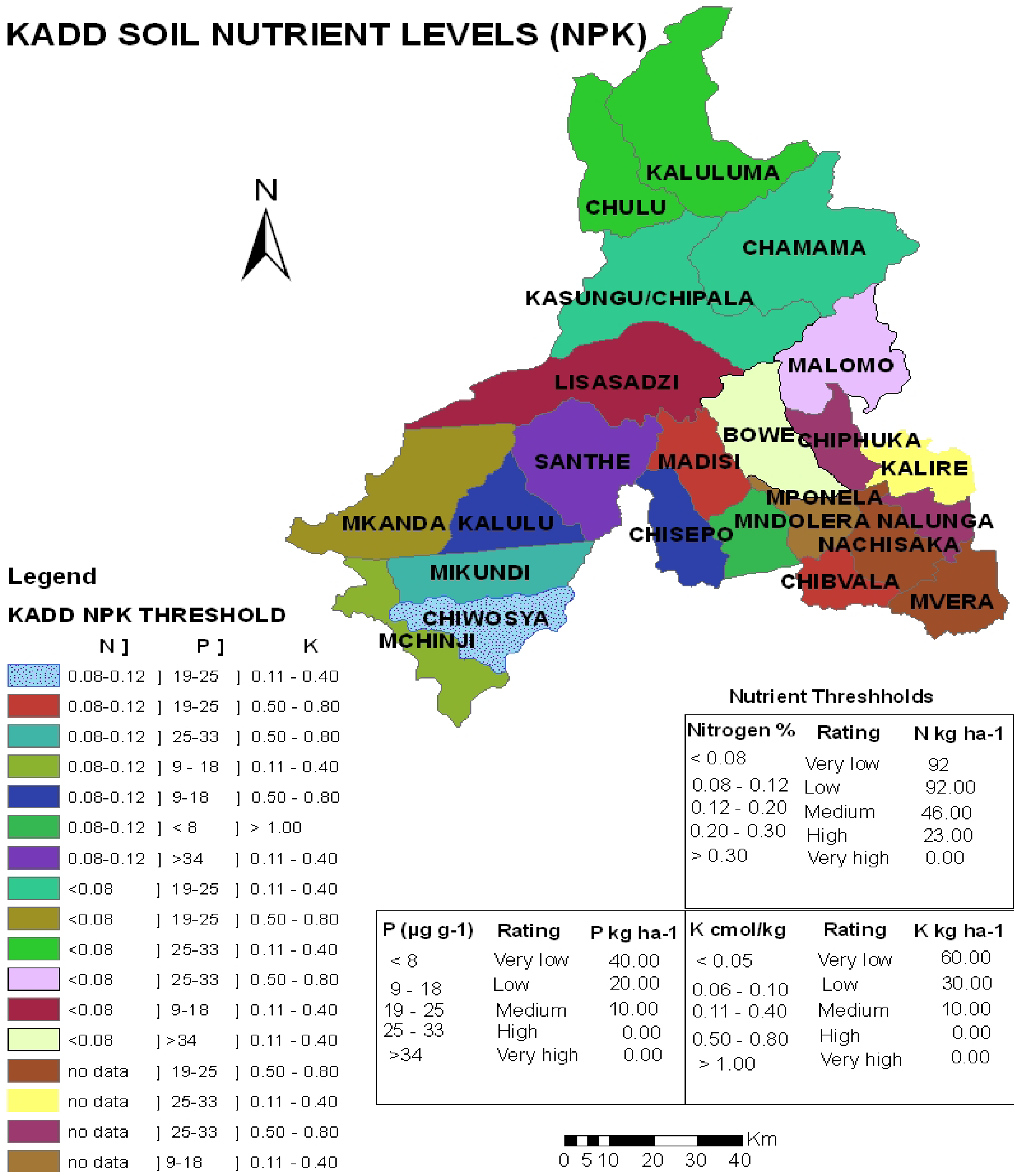
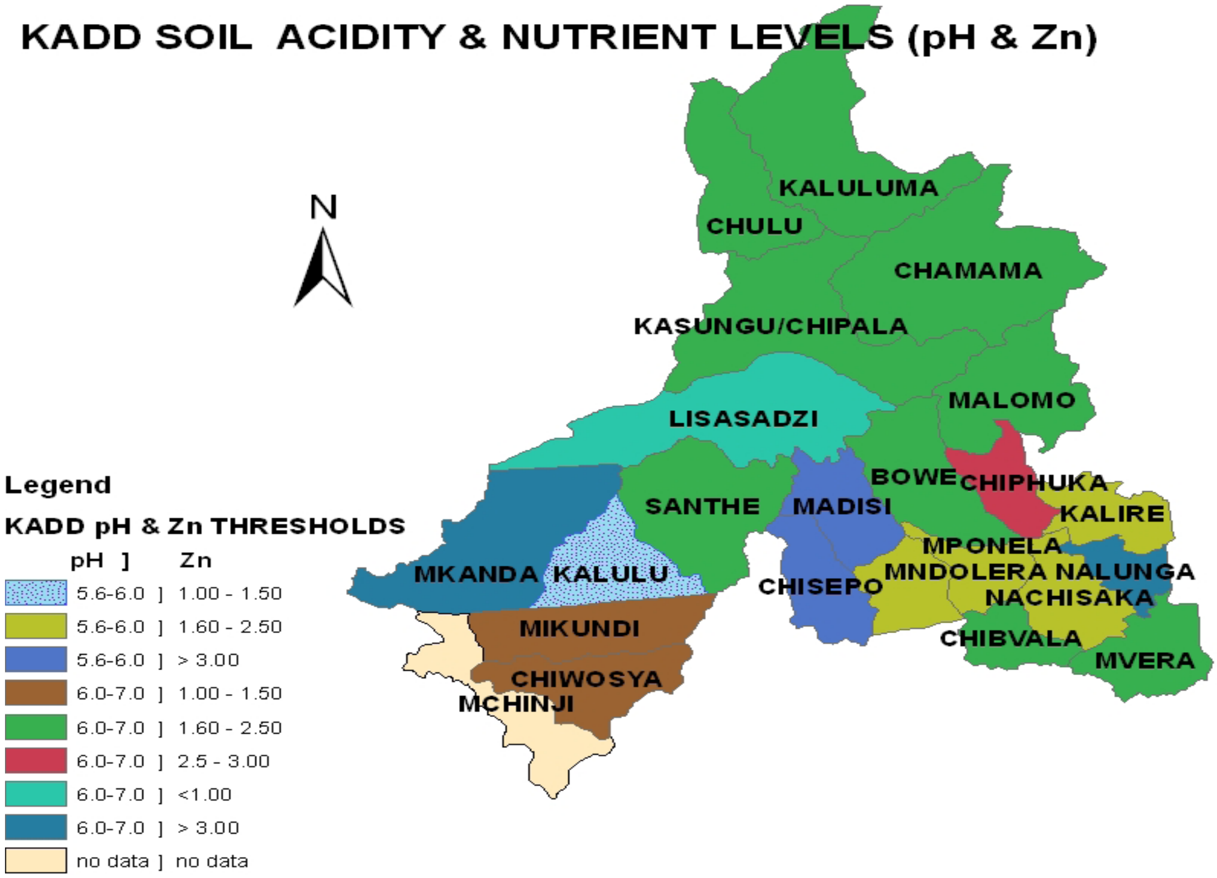


Figure 10: *Map of Kasungu Agricultural Development Division (KADD) showing NPK nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

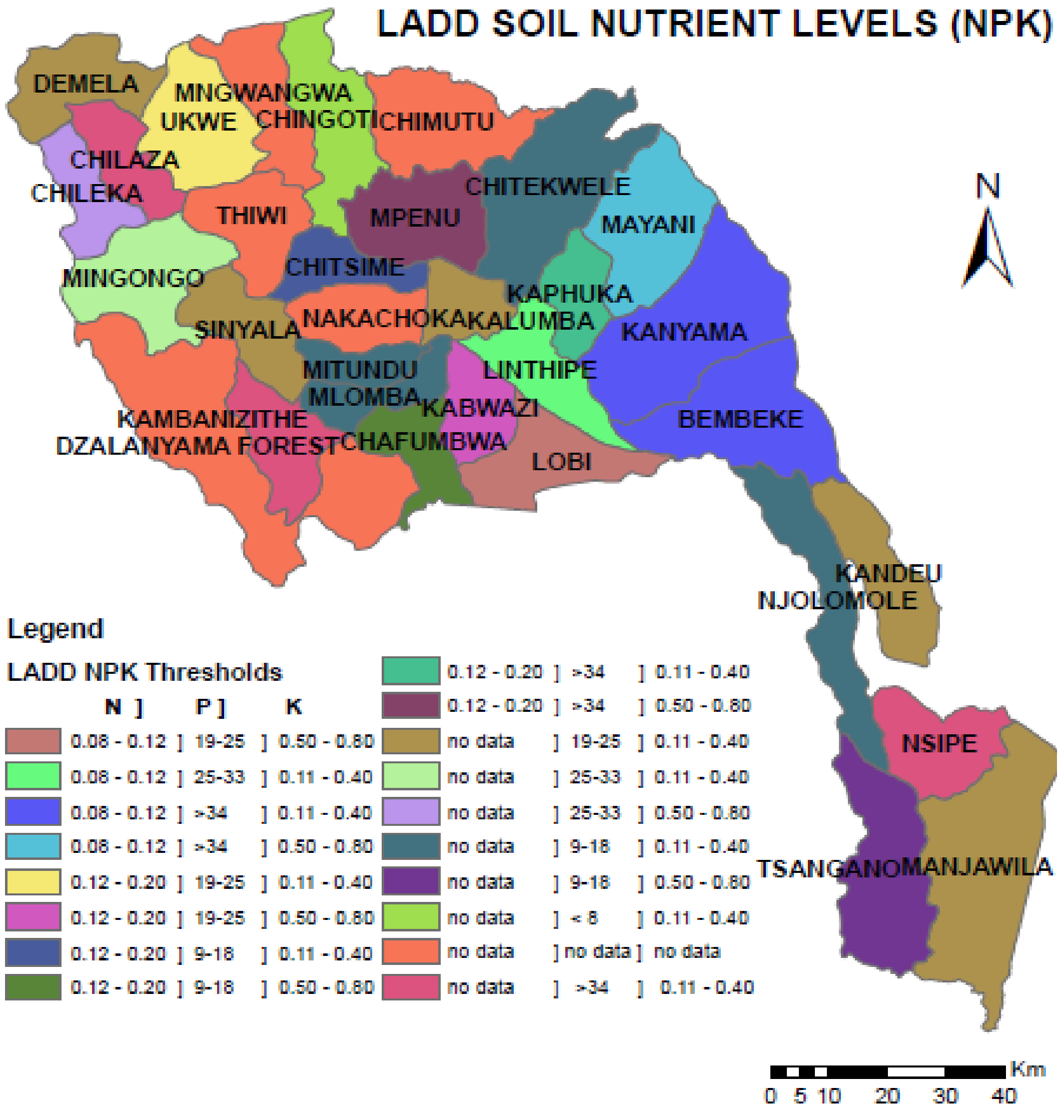


Nutrient Thresholds

Soil pH	Rating	Dolomitic lime t ha-1	Zinc µg g-1	Rating	Zn kg ha-1
< 4.5	Very strongly acid	4.00	<1.00	Very low	4.00
4.5 - 5.0	Strongly acid	2.00	1.00 - 1.50	Low	2.00
5.1 - 5.5	Acid	2.00	1.60 - 2.50	Medium	0.00
5.6 - 6.0	Moderately acid	2.00	2.5 - 3.00	High	0.00
6.0 - 7.0	almost neutral	0.00	> 3.00	Very high	0.00

Km
0 5 10 20 30 40

Figure 11: *Map of Kasungu Agricultural Development Division (KADD) showing soil pH and Zn nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*



Nutrient Thresholds

Nitrogen %	Rating	N kg ha-1	P (µg g-1)	Rating	P kg ha-1	K cmol/kg	Rating	K kg ha-1
< 0.08	Very low	92	< 8	Very low	40.00	< 0.05	Very low	60.00
0.08 - 0.12	Low	92.00	9 - 18	Low	20.00	0.06 - 0.10	Low	30.00
0.12 - 0.20	Medium	46.00	19 - 25	Medium	10.00	0.11 - 0.40	Medium	10.00
0.20 - 0.30	High	23.00	25 - 33	High	0.00	0.50 - 0.80	High	0.00
> 0.30	Very high	0.00	>34	Very high	0.00	> 1.00	Very high	0.00

Figure 12: *Map of Lilongwe Agricultural Development Division (LADD) showing NPK nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

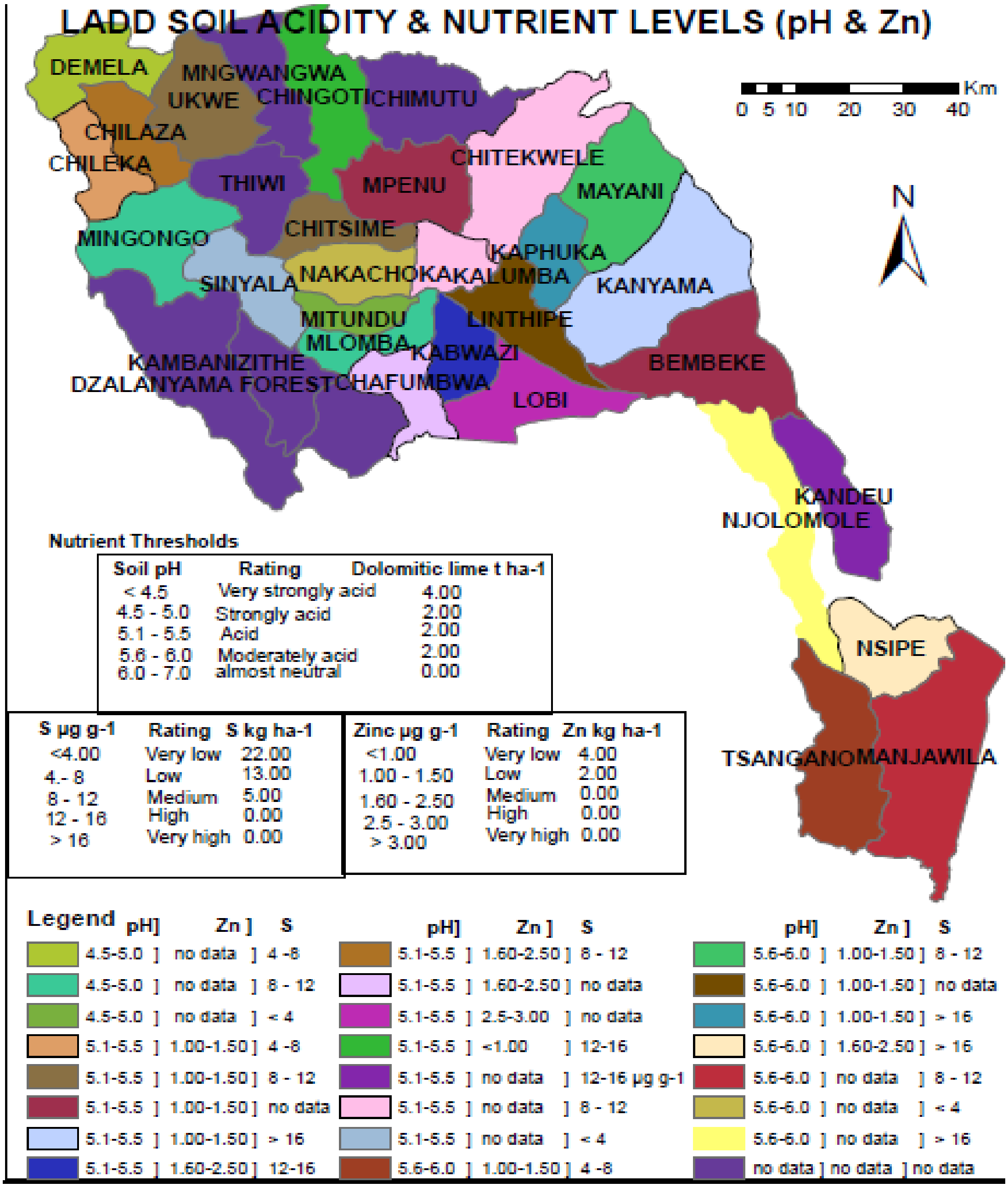
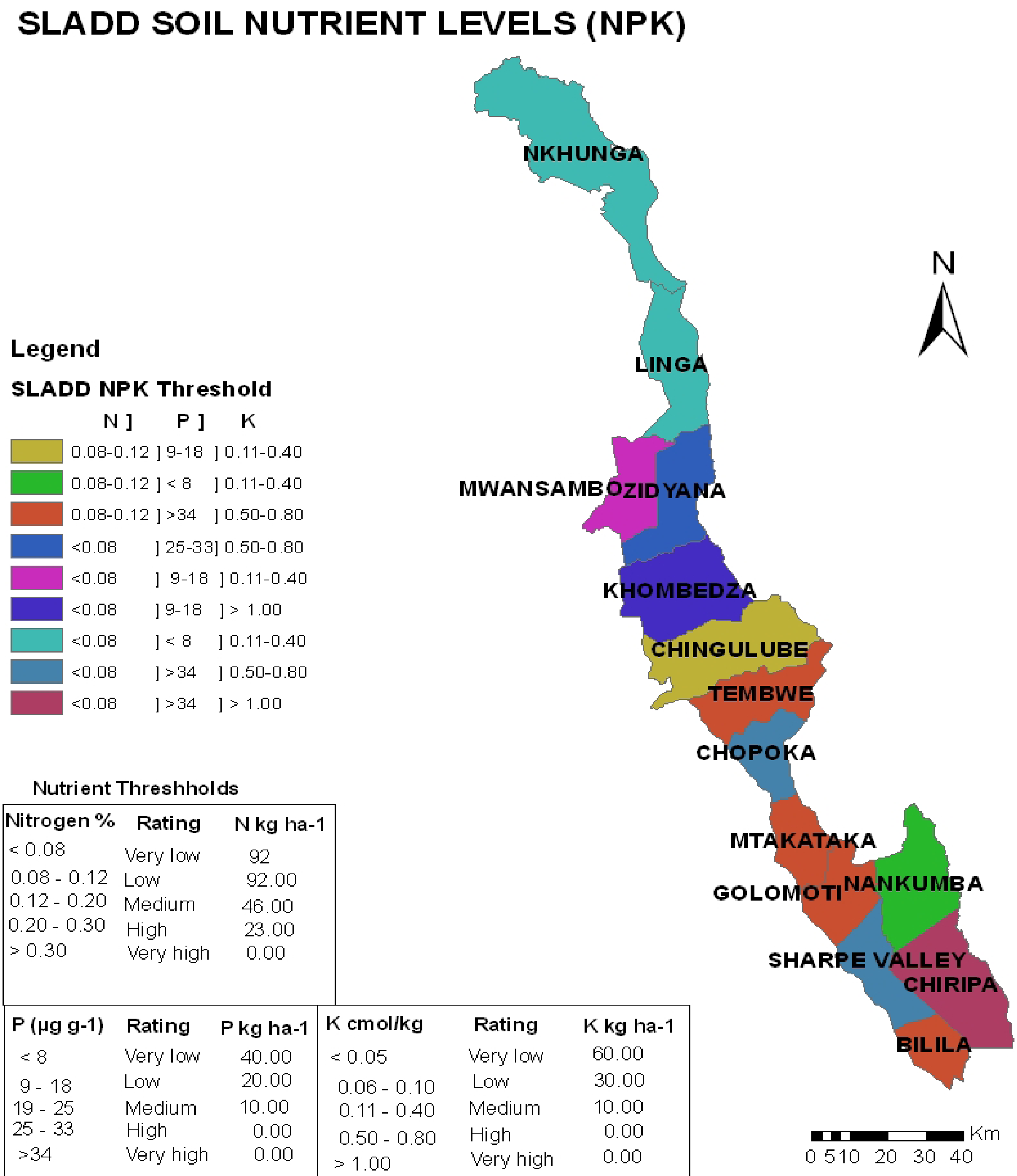


Figure 13: *Map of Lilongwe Agricultural Development Division (LADD) showing pH, Zn and S nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*



Nutrient Threshholds

Nitrogen %	Rating	N kg ha-1
< 0.08	Very low	92
0.08 - 0.12	Low	92.00
0.12 - 0.20	Medium	46.00
0.20 - 0.30	High	23.00
> 0.30	Very high	0.00

P (µg g-1)	Rating	P kg ha-1
< 8	Very low	40.00
9 - 18	Low	20.00
19 - 25	Medium	10.00
25 - 33	High	0.00
>34	Very high	0.00

K cmol/kg	Rating	K kg ha-1
< 0.05	Very low	60.00
0.06 - 0.10	Low	30.00
0.11 - 0.40	Medium	10.00
0.50 - 0.80	High	0.00
> 1.00	Very high	0.00

***Figure 14**: Map of Salima Agricultural Development Division (SLADD) showing NPK nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

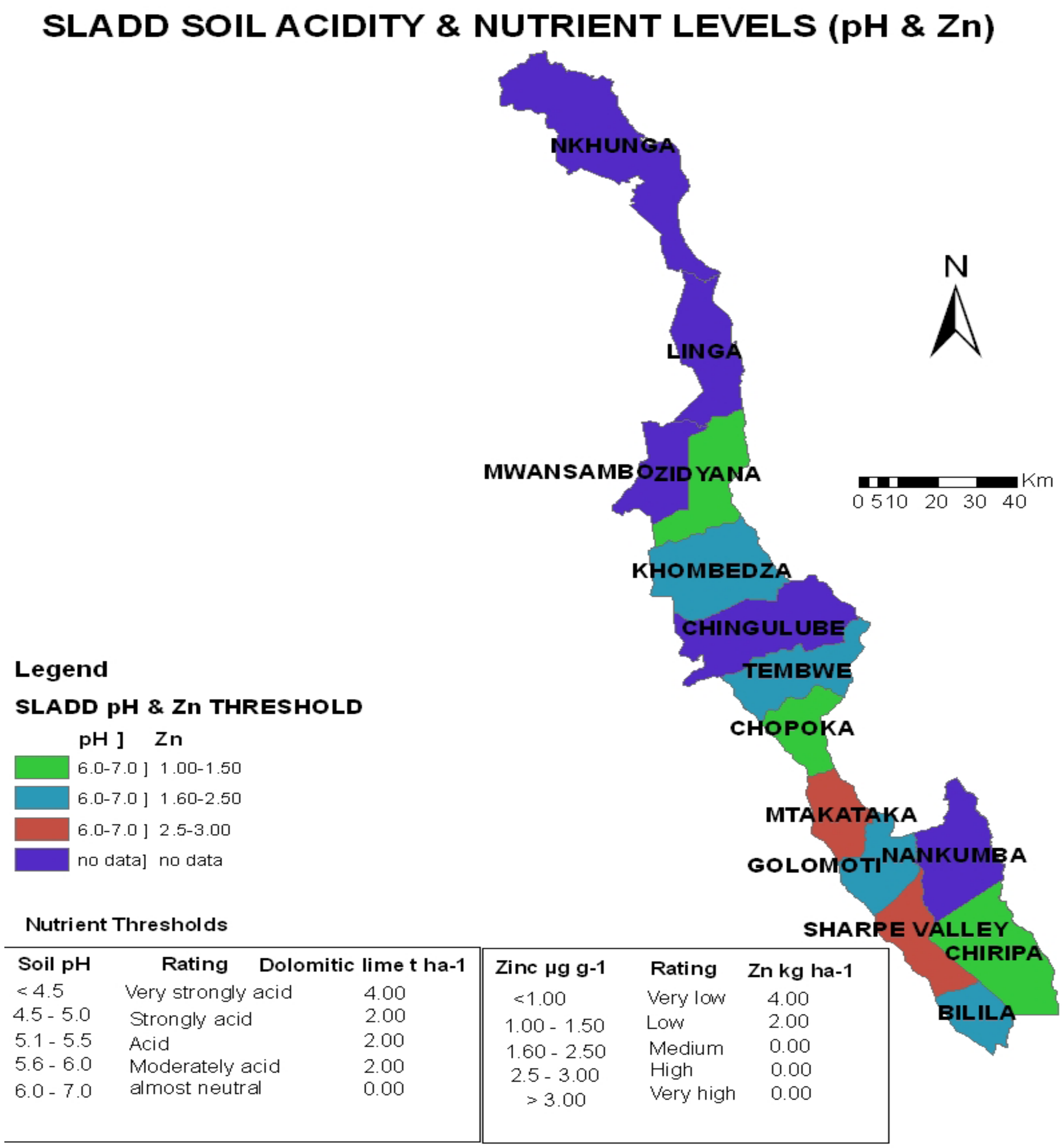


Figure 15: *Map of Salima Agricultural Development Division (SLADD) showing pH and Zn nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

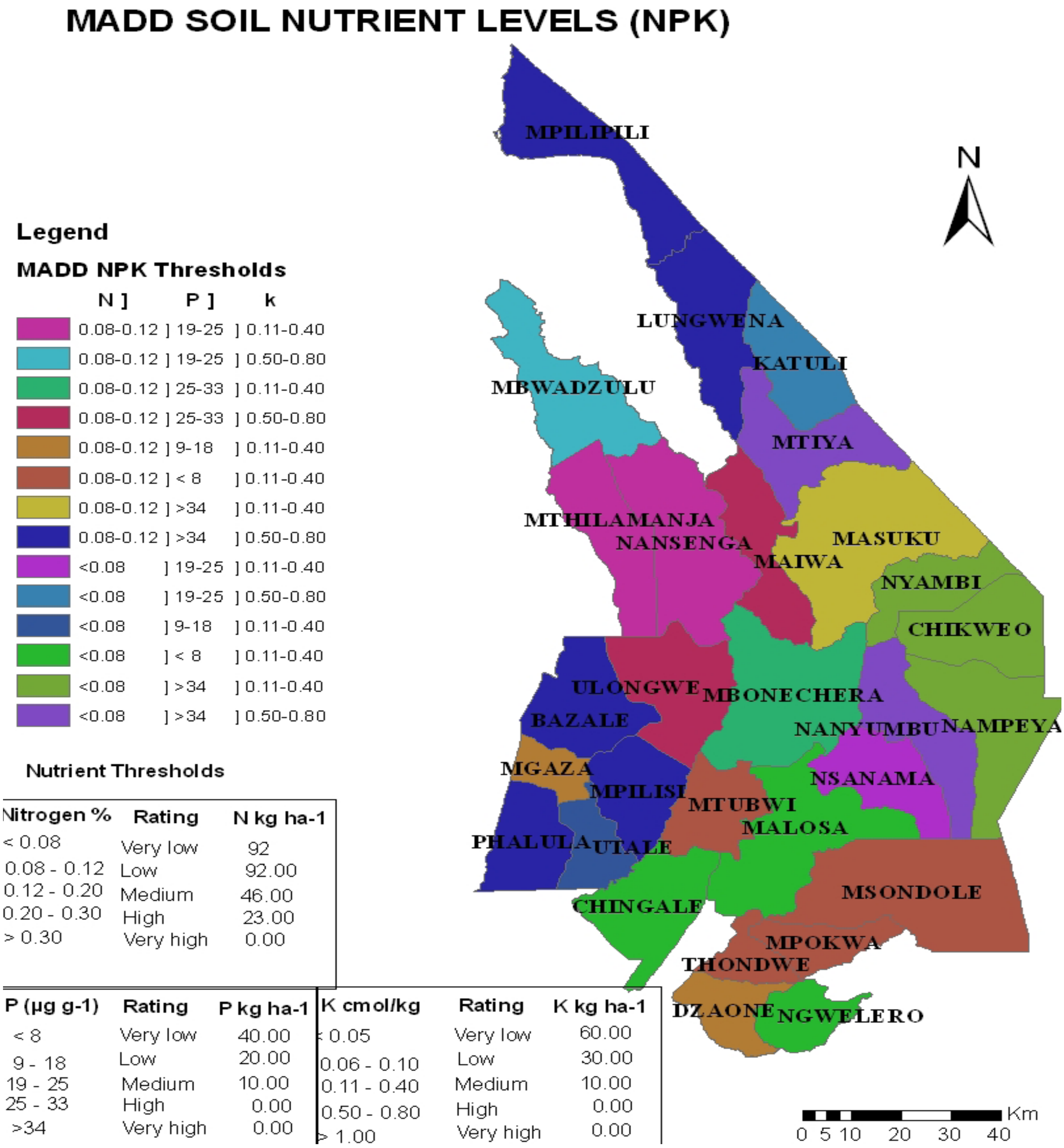


__Figure 16__: Map of Machinga Agricultural Development Division (MADD) showing NPK nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)

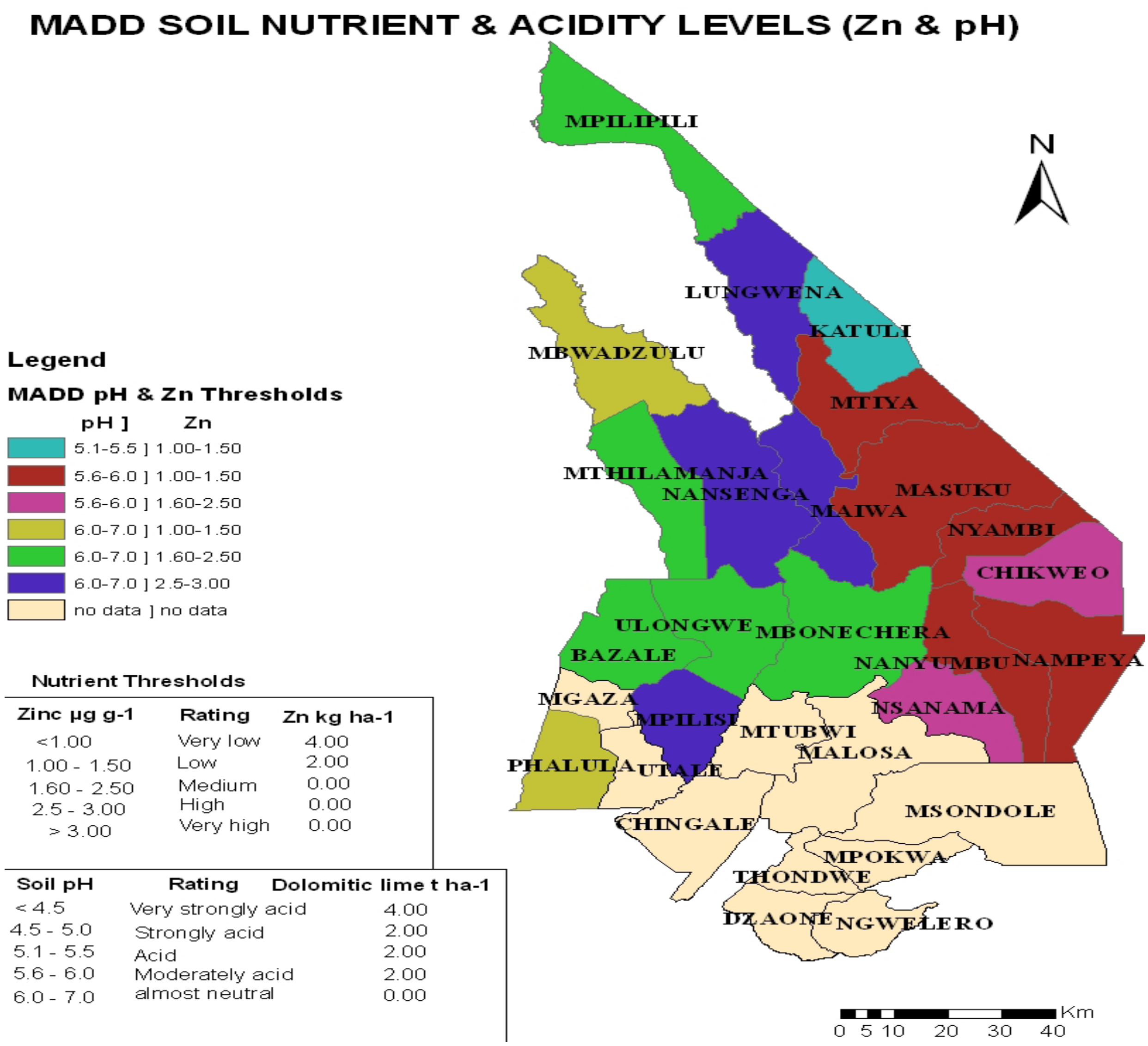
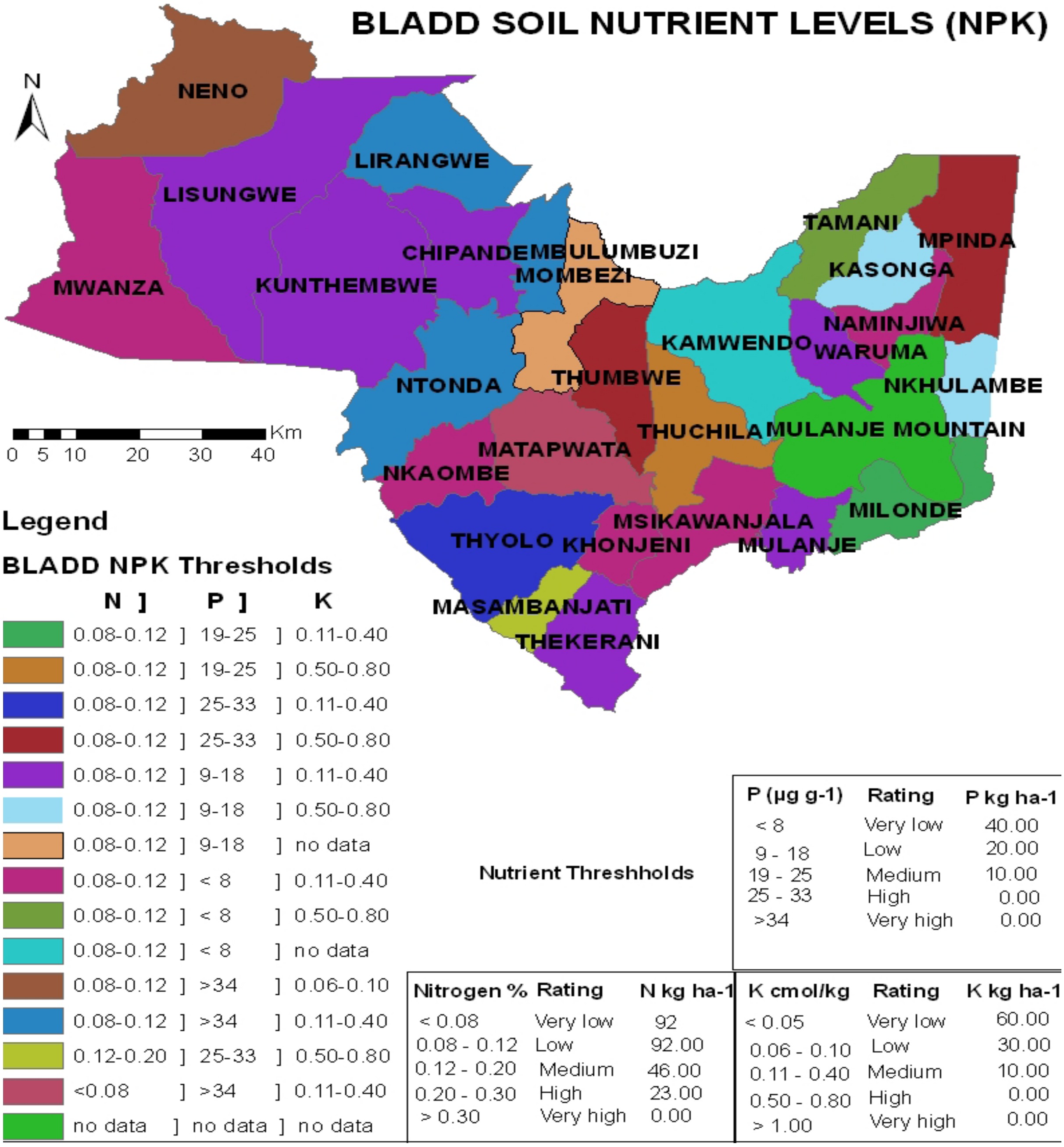


Figure 17: *Map of Machinga Agricultural Development Division (MADD) showing pH and Zn nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

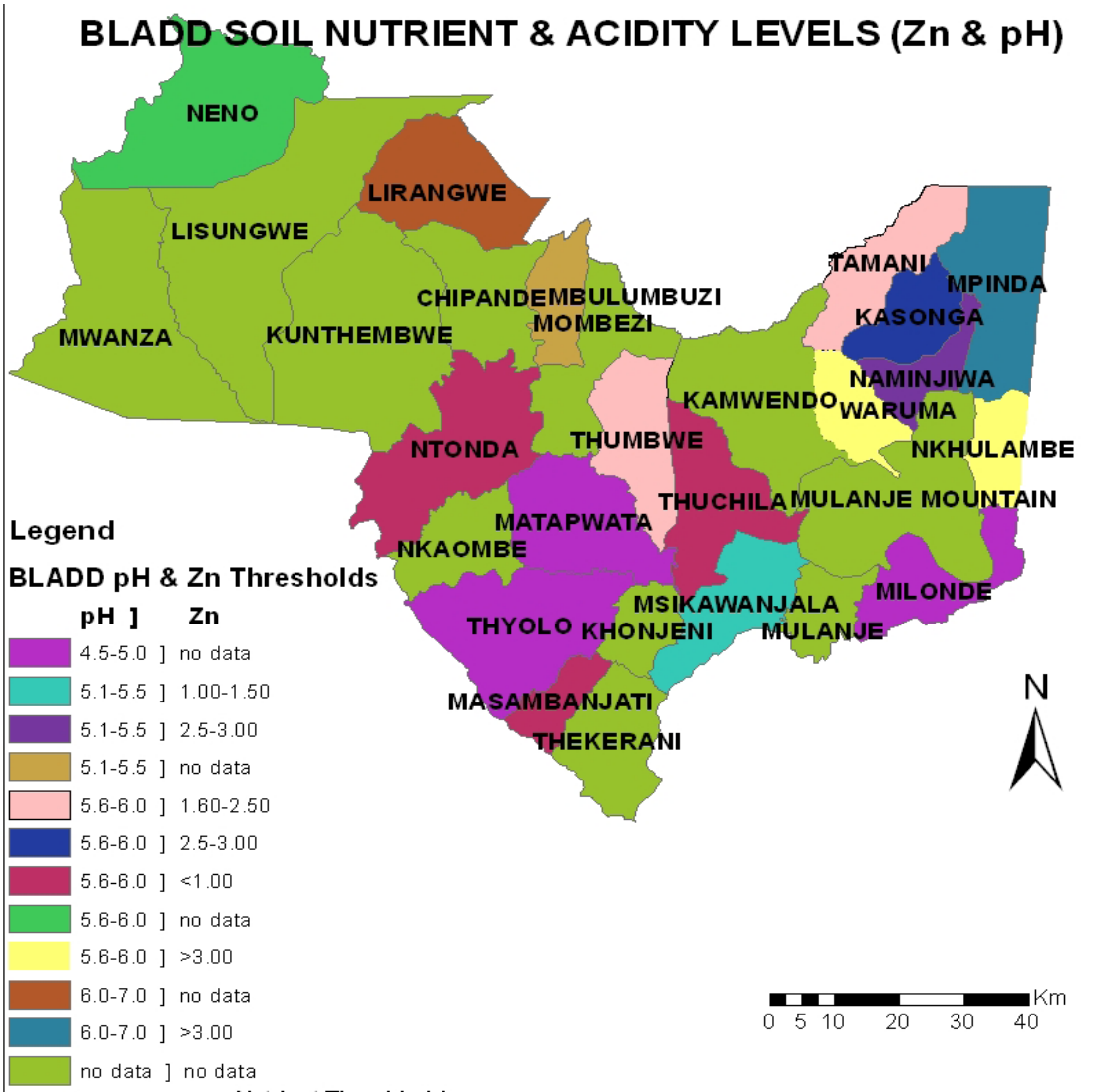


P (µg g-1)	Rating	P kg ha-1
< 8	Very low	40.00
9 - 18	Low	20.00
19 - 25	Medium	10.00
25 - 33	High	0.00
>34	Very high	0.00

Nitrogen %	Rating	N kg ha-1
< 0.08	Very low	92
0.08 - 0.12	Low	92.00
0.12 - 0.20	Medium	46.00
0.20 - 0.30	High	23.00
> 0.30	Very high	0.00

K cmol/kg	Rating	K kg ha-1
< 0.05	Very low	60.00
0.06 - 0.10	Low	30.00
0.11 - 0.40	Medium	10.00
0.50 - 0.80	High	0.00
> 1.00	Very high	0.00

Figure 18: *Map of Blantyre Agricultural Development Division (BLADD) showing NPK nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

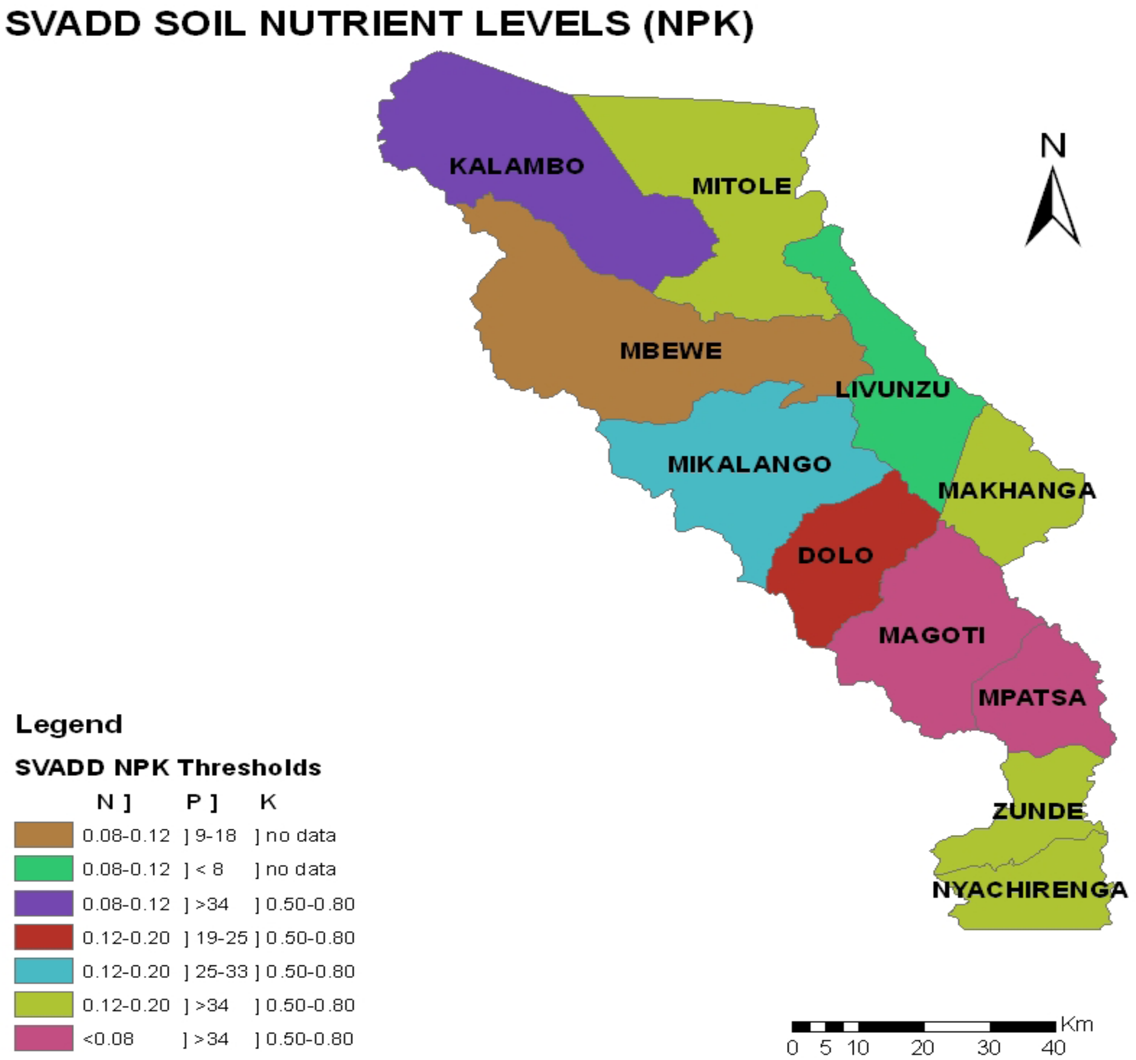


Nutrient Threshholds

Soil pH	Rating	Dolomitic lime t ha-1
< 4.5	Very strongly acid	4.00
4.5 - 5.0	Strongly acid	2.00
5.1 - 5.5	Acid	2.00
5.6 - 6.0	Moderately acid	2.00
6.0 - 7.0	almost neutral	0.00

Zinc µg g-1	Rating	Zn kg ha-1
<1.00	Very low	4.00
1.00 - 1.50	Low	2.00
1.60 - 2.50	Medium	0.00
2.5 - 3.00	High	0.00
> 3.00	Very high	0.00

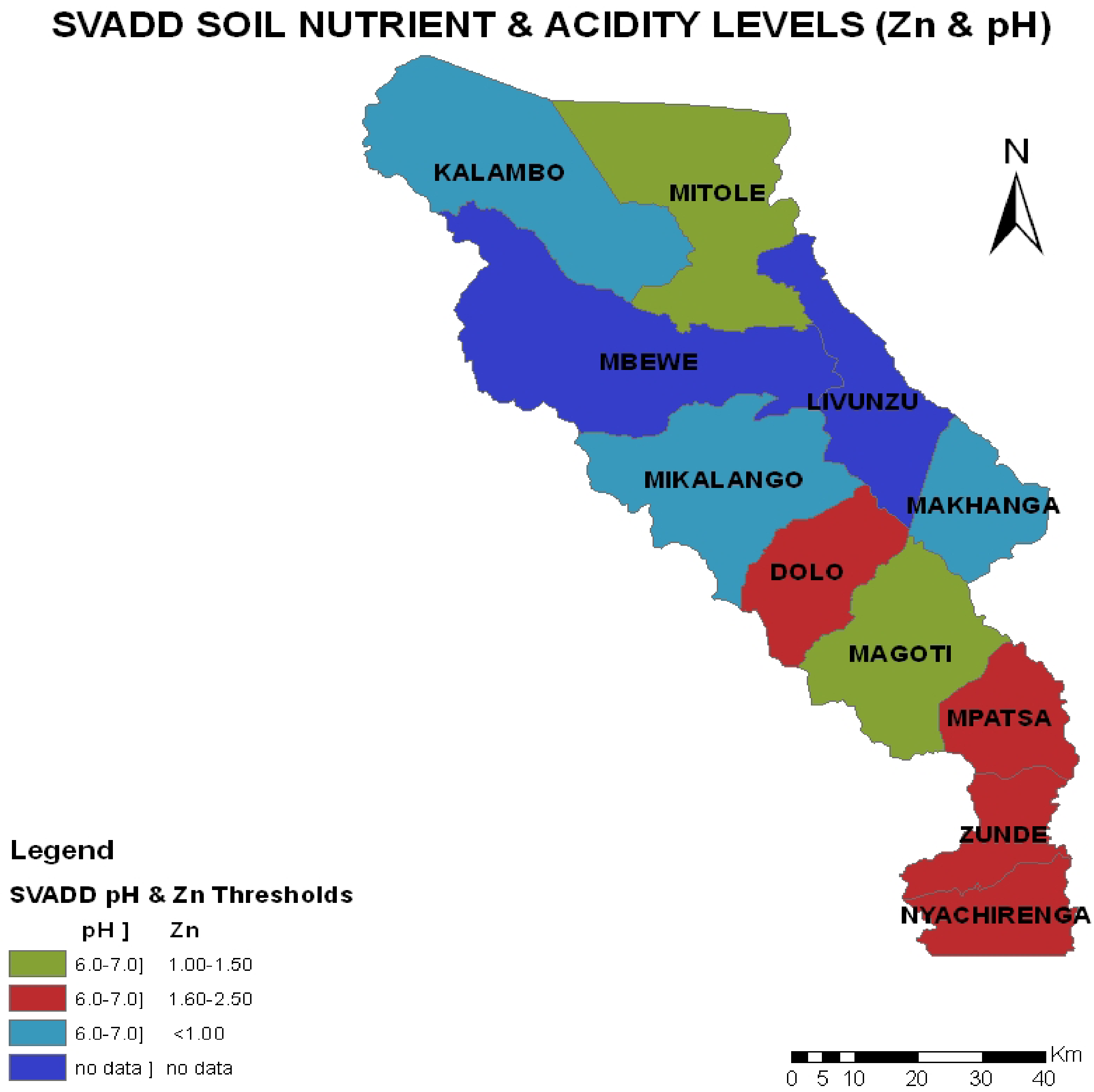
Figure 19: *Map of Blantyre Agricultural Development Division (BLADD) showing pH and Zn nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*



Nutrient Threshholds

Nitrogen %	Rating	N kg ha-1	P (µg g-1)	Rating	P kg ha-1	K cmol/kg	Rating	K kg ha-1
< 0.08	Very low	92	< 8	Very low	40.00	< 0.05	Very low	60.00
0.08 - 0.12	Low	92.00	9 - 18	Low	20.00	0.06 - 0.10	Low	30.00
0.12 - 0.20	Medium	46.00	19 - 25	Medium	10.00	0.11 - 0.40	Medium	10.00
0.20 - 0.30	High	23.00	25 - 33	High	0.00	0.50 - 0.80	High	0.00
> 0.30	Very high	0.00	>34	Very high	0.00	> 1.00	Very high	0.00

Figure 20: *Map of ShireValley Agricultural Development Division (SVADD) showing NPK nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*



Nutrient Thresholds

Soil pH	Rating	Dolomitic lime t ha-1	Zinc µg g-1	Rating	Zn kg ha-1
< 4.5	Very strongly acid	4.00	<1.00	Very low	4.00
4.5 - 5.0	Strongly acid	2.00	1.00 - 1.50	Low	2.00
5.1 - 5.5	Acid	2.00	1.60 - 2.50	Medium	0.00
5.6 - 6.0	Moderately acid	2.00	2.5 - 3.00	High	0.00
6.0 - 7.0	almost neutral	0.00	> 3.00	Very high	0.00

Figure 21: *Map of ShireValley Agricultural Development Division (SVADD) showing pH and Zn nutrient status with application recommendations. (Source: Chilimba and Nkosi, 2014)*

4.7 Fertilizer Recommendations developed from these maps

- Low soil N, P, K, S and Zn concentration use the following fertilizer recommendation: Basal dress with 4 bags 23.10.5+6S+1.0 Zn per hectare. Top dress with 4 bags with the same 23.10.5+6S +1.0 Zn. This recommendation will supply 92 kg N, 40 Kg P_2O_5, 20 kg K_2O, 24 kg S and 4 kg Zn.
- Adequate soil K and Zn but low soils P concentration use the following fertilizer recommendation: Use 4 bags 23.21.0+4S top dress with 2 bags urea in upland soils. This recommendation will supply 92 kg N, 42 Kg P_2O_5, 0 kg K_2O, 8 kg S and 0 kg Zn. In Shire Valley and Lakeshore top dress with 4 bags sulphate of ammonia or ammonium nitrate per hectare because under high soil pH urea is not recommended.
- Adequate soil P, K, S and Zn, basal dress with two bags urea or 3 bags calcium ammonium nitrate and top dress with 2 bags urea or 3 bags calcium ammonium nitrate per hectare. This recommendation will supply 86 - 89 kg N or basal with urea and top dress with urea supplying 92 kg N ha^{-1}.
- Low soil N, P, K, S and Zn but cannot manage the first recommendation, basal dress with 4 bags 23.10.5+6S+1.0 Zn and top dress 2 bags with urea in upland soils and top dress with 4 bags sulphate of ammonia in Lakeshore and Shire Valley per hectare supplying 92 kg N, 20 kg P_2O_5, 10 kg K_2O, 12 kg S, 2 kg Zn ha^{-1} and 88 kg N, 20 kg P_2O_5, 10 kg K_2O, 60 kg S, 2 kg Zn ha^{-1} respectively.
- Low soil N, P, K, S but adequate Zn farmers can basal dress with 4 bags of 50 kg super D compound (NPK 10:24:20 + 7S) and top dress with 3 bags urea to supply 89 kg N, 48 kg P_2O_5, 40 kg K_2O, 14 kg S ha^{-1} .

Chapter 5: Other issues related to fertilizer recommendation in Malawi

5.1 Timing of fertilizer application

Malawi data show that splitting nitrogen fertilizer application in Malawi is most effective on the lighter soils (Ngwira and Nhlane, 1986; Saka and Chisenga, 1990). Many smallholders delay applying the basal fertiliser until some weeks after planting. This has a serious effect on fertilizer use efficiency (Ngwira and Nhlane, 1986; Kabambe and Kumwenda, 1995; Kumwenda 1994). Research conducted on farmers' fields by Kabambe and Kumwenda (1995) showed a reduction in maize yield of 700 to 1500 kg/ha when the basal dressing fertilizer containing nitrogen and phosphorus was applied 2 weeks after planting. Data from 157 on-farm trials by Sakala (1998) in the 1994/95 season indicated that delaying the basal dressing fertilizer for maize by 4 weeks after planting can result in yield reduction by 1000 to 1500 kg/ha.

5.2 Fertilizer placement

In fertilizer demonstrations carried out in 1996/1997, dolloping was more labour intensive than banding, and increased yields but not significantly (Figure 22). Where labour is a constraint, then broadcasting could make more economic sense than dolloping.

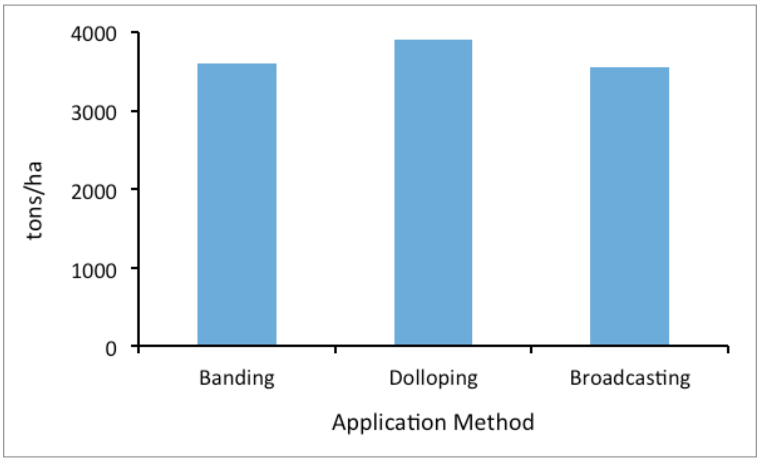


Figure 22: *Relationship between fertilizer placement methods and maize yield.*
(Adapted from a presentation by Benson T.D.)

http://www.slideee.com/slide/maximizing-returns-to-fertilizer-use-on-maize-in-malawi-lessons-from-on-farm-agronomic-research-by-todd-benson-ifpri

5.3 Weeding

The interaction between crop yield and weed management is high. Weeds compete with crops for soil nutrients, soil water and light, reducing maize yields by more than 50 percent (Kabambe and Kumwenda 1995). Many smallholder farmers in southern Africa use animal draft power to control weeds - but few Malawi farmers own cattle. Thus most weeding is done by hand - a labour intensive and time-consuming operation where timing is critical to success. Weeding twice, but at the appropriate times, could give higher yields of maize on half the fertilizer, than weeding once and using the full recommendation (Figure 23).

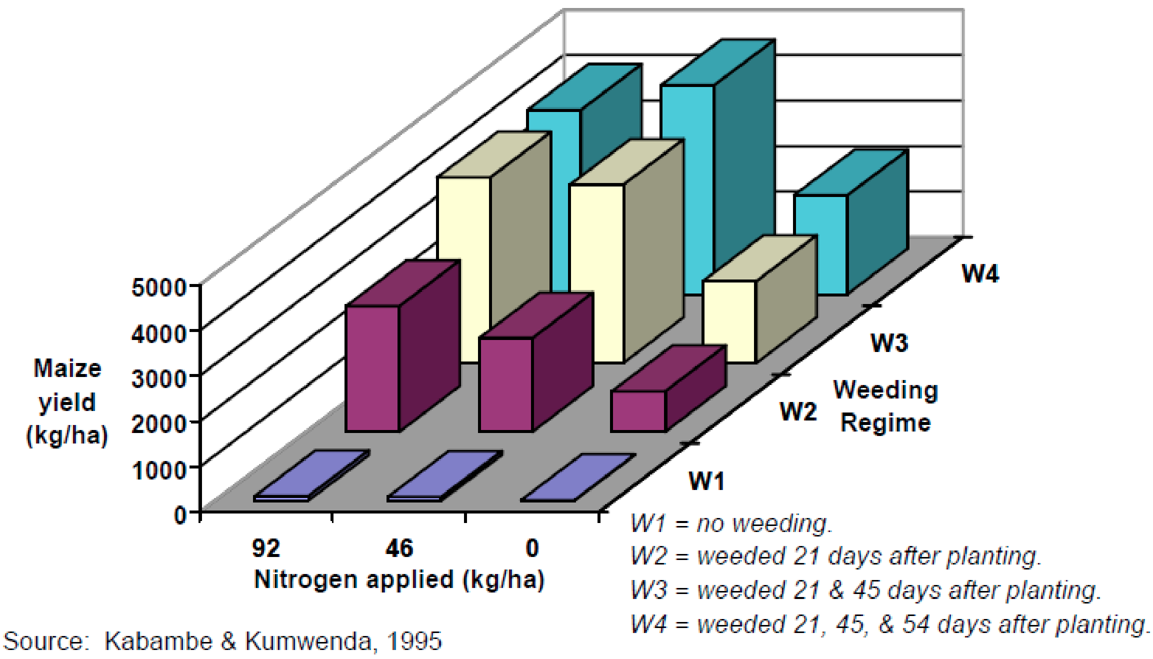


Figure 23: *Effect of different weeding levels on maize yield*

5.4 Fertilizer market in Malawi

In Malawi, the government was actively involved in promoting smallholder maize production during the 1970s and 1980s. Pan-territorial pricing was used to encourage production in the more remote Northern districts and maize producer prices and fertilizer were subsidized through taxation of smallholder cash crops (Jayne and Jones 1997). All fiscal and economic subsidies on fertilizer were removed in 1995/96 leading to an increase in fertilizer prices varying between 200 and 300 %. As a result, fertilizer consumption started to decline despite the fact that one third of it was distributed for free by the government (Townsend 1999). At the end of the 1990s the commercial fertilizer market was dominated by a few private sector importers/wholesalers and an expanding network of small stockists but government institutions still continued to import fertilizer (Townsend 1999). Moreover, the parastatal maize marketing board continues to exist in Malawi (Kelly et al. 2005).

In 2002, Malawi liberalized its agricultural input markets, but the public sector continues to participate in the fertilizer market. Government participation at the procurement and distribution levels varies from year to year, depending on subsidy program decisions. The strength of the Government network is its ownership of 58 Smallholder Farmers Fertilizer Revolving Fund (SFFRFM) depots and more than 600 Agricultural Development and Marketing Corporation (ADMARC) market units. The latter have not been active since 2005, apart from distributing subsidized fertilizer in 2005- 2006 and 2006-2007 seasons, which significantly undermined the private stockists (small retailers) emerging under the AISAM and CNFA networks. In parallel with these two agricultural campaigns, about a dozen firms were involved in fertilizer procurement— primarily imports, with some processing. These importers supply a formal network of more than 400 retail outlets in Malawi (public and private sector combined), in addition to an informal network of independent agro dealers with an estimated 226 active dealers. Many of these smaller dealers were driven out of business in the two agricultural campaigns by the government's subsidy program. The Malawi market in 2006-2007 was estimated to be almost 260,000 metric tons of fertilizer products, representing a 16 % increase over the previous year (IFDC 2007). This is mainly due to a subsidized fertilizer program initiated by the government, amounting to 170,000 metric tons. The annual market over the past 10 years has fluctuated between 167,000 and 224,000 metric tons due to shifting government policies and periodic drought conditions (FAOSTAT 2011). Inconsistent government policies have frustrated the vibrant private sector procurement and marketing of fertilizer. The Malawian fertilizer market is an oligopoly, with the government playing an active role-from importation to final delivery — through a public tender to receive private sector bids to procure subsidized fertilizers. Players include international companies with country offices (Yara Malawi, Export Trading Co), importer producers (Optichem, Farmers World, Agora), and independent traders (Sealand Investment, Agricultural Trading Company, Simama General Dealers Company).

Many importers are vertically integrated, which contrasts with fertilizer markets in the other countries studied. While importers in the other countries are often wholesalers, few are also distributors and retailers, as is the case in Malawi. Another difference in Malawi is that the government can still play a role anywhere along the market chain, from importer all the way to the level of retailer. The uncertainty surrounding government intentions from year to year causes this marketplace to be riskier for private sector investment and market development. Experience in the last three years has influenced the government's thinking on its proper role, as have donor nations, which fund the subsidy (voucher) program. Subsidy policy uncertainties include annual timing, volume allocations, tender currency choice, validity of quoted prices, and payment delays (Sommers et al., 2013). These markets are characterized by too many products relative to market size. For example, Malawi has 20 fertilizer products in use. Many are compound fertilizers, typically NPK with minor variations in content. Because these are low analysis fertilizers, the nutrients are more expensive than the same nutrients found in straight high analysis fertilizers, because it is more expensive to manufacture smaller amounts of specific types of fertilizers. As a result, there is poor availability of fertilizers in rural areas and high prices for fertilizers that do reach the farm-gate. The seasonality of demand for fertilizers and the low purchasing power of smallholder farmers which is typically characterized by small and frequent purchases increase transportation, storage and transaction costs.

5.5. Farm-scale heterogeneity and fertilizer recommendations

A distinctive feature that characterizes smallholder farming systems in much of Sub-Saharan Africa (SSA) is the wide diversity of farming households and marked heterogeneity for both biophysical and socio-economic conditions, at short ranges (e.g. Zingore at al. 2007; Tittonell et al. 2005). Resource availability and the pattern of resource allocation to different activities are determined by household 'wealth', and also depend on household priorities and production objectives. Therefore, the intensity of nutrient use varies between farms of different resource endowment and production orientation, leading to variation in soil fertility status and crop productivity at the farm level. Technological interventions to address the problem of poor productivity of smallholder agricultural systems must be designed to target these socially diverse and spatially heterogeneous farms and farming systems (Tittonell et al. 2010). A study by Kamanga et al. (2009); and Kamanga (2011) used a combination of survey and participatory methods to categorize 136 smallholder farmers from Chisepo, central Malawi, into four resource groups (RGs), comprising high-resourced (RG1; 5%), medium resourced (RG2; 10%), low-resourced (RG3; 47%) and least-resourced group (RG4;38%). The study investigated the link between household access to assets and diversity in livelihood strategies and investments in soil fertility management in central Malawi. Analysis of farmer resources endowment and their relation to soil fertility revealed that soil fertility management is intricately influenced by ownership of assets. RG1 and RG2 farmers owned more resources including cattle, had larger fields (about 5 ha), hired-in labour for timely farm operations, earned more income and invested more in soil fertility improvement. RG3 and RG4, comprising the majority, were resource constrained and did not invest adequately in improving soil fertility, with about 50% of them owning between 0.5-1 ha land. They had large food deficits due to poor crop yields. These farmers supplemented their farm income through Ganyu, a local practice of casual work on resource-endowed farmers' fields in exchange for food or cash.

This study established that there is a huge variability in fertilizer use linked to farm and field type, with average N application of 44 kg N/ha for a home fields in RG1 but only about 10 kg N/ha in the same fields belonging to RG3 farmers. Farmers in RG4 applied no fertilizer at all. Farmers' soil fertility management was directly determined by the level of assets of a household, which influence the amounts of resources such as mineral fertilizer and manure a household can use. In line with other studies, soil fertility decreased from home fields to remote fields in each farmer group, and also decreased from fields belonging to RG1 to those in RG4. Soil fertility indicators for home fields belonging to resource-constrained farmers (RG4) were low and of similar magnitude to those measured for the remote fields belonging to resource-endowed farmers (RG1).

Experimental results showed that maize grain yields over a four-year period were greater for RG1 and RG2 than RG3 and RG4 farms. Maize-pigeon pea intercrops gave consistent positive returns across resource groups and were the only technology to provide positive returns to labour for RG4 farmers. Use of pigeon pea was overall the least risky option, and was especially suited to least-resourced farmers. The majority of resource-constrained farmers in Malawi were not able to invest in mineral fertilizers to improve crop yields, and inclusion of grain legumes, such as pigeon pea, offered the best opportunity for these resource-constrained farmers to access protein while improving their soils through litter-fall. This study also established that RG3 and RG4 farmers had less access to legume seed, resulting in less adoption of grain legumes. In general, Malawi's low livestock densities (Benson et al. 2002) limit the use of manure.

Chapter 6: Fertilizer recommendation issues emerging from Livingstonia Workshop

Due to growing recognition of the importance of fertile soils and the need for understanding appropriate fertilize application rate, time and place among the African governments; the Malawi government requested AGRA to support it in understanding the fertilizer recommendation needs for various Malawi agricultural zones. Malawi is sub-divided into five Agricultural Development Divisions (ADDs), each representing an agro-ecological zone with wide variations in soil characteristics and climatic conditions. In spite of these variability, the fertilizer use for most crops is based on blanket recommendations. The AGRA Soil Health Program convened the workshop held between August 27-28 at the Livingstonia Hotel near Salima. A total of 35 professionals encompassing the soil experts, seed experts, economists, spatial analysts and extension experts drawn from CGIAR centres, International Fertilizer Organizations, International and local development organizations, farmer support bodies, input-output market actors, government agencies and universities were mobilized under the auspices of the Malawi soil health consortium. The purpose was to understand the gaps, challenges and opportunities for fertilizer recommendation for key crops based on studies from multiple partners and high level expert deliberation and transmit the findings to Government officials and local donors. Over the three days over 10 presentations and deliberations were made on such issues as soil fertility status of the 5 ADDs, Fertilizer recommendation efforts, special issues regarding legumes and cereals, acidic soils, fertilizer policies and the input-output market situation in Malawi. The group recommendations were as follow.

Synthesized Recommendations for presentation to policy makers

After deliberations on the state of Malawi soils, agro climatic conditions, topographies, crops, policies and wealth status of majority of the smallholder farmers the following recommendations were arrived at:

1. Continue Farm Input Subsidy Program (FISP) to provide food security

a. Revert to the original 70% subsidy provided by government.

   Target it as follows:

   - Bottom 20% poor smallholder: cash transfers.
   - 60% Middle (60% of 2.45 mill of the farming population) 600,000 – 700,000 of the farming population should be FISP focus group
   - 20% high income class – are able to purchase inputs

b. Improve cost efficiencies in FISP

The following strategies will improve effectiveness

- Procurement and evaluation of bids should be done by a neutral agency.
- Provide technical support to the independent body managing the subsidy programme to strengthen capacity and increase transparency.
- Expedite enactment of The Fertilizer Bill and Fertilizer Policy, to ensure transparency and donor support. Fertilizer procurement should be gradually transferred to the private sector.

2. *Improve fertilizer use efficiencies through better agronomic practices*

- Target: Double the Agronomic Use Efficiency of N, from the present 12 – 14 kg maize grain/ kg N fertilizer applied.
- Blanket fertilizer re commendations should be gradually replaced by site specific recommendations.
- Soil mapping and rapid soil testing should be the basis of fertilizer recommendations.
- Facilitate expansion of private fertilizer blending plants across the country to provide the right fertilizer formulas recommended by rapid soil testing.

3. *Expand FISP for Wealth Creation –Grain Legumes*

- Focus on scaling up soybean, pigeon pea, groundnuts, and common bean, in response to market opportunities.
- Increase farmer access to improved legume seeds through support of private seed industry.
- Increase commercially available, high quality inoculum for soybeans.
- Promote fertilizer blends targeted for legumes. Update and provide agronomic recommendations
- Attract and support private sector investments in agriculture
- Hold an investment forum: leaders of private agribusiness companies and banks (national and international ones).
- Develop innovative financing including risk sharing facilities.
- Identify and support scaling up of innovative, successful farming system models that integrate small scale farmers.

4. *Strengthen Extension Services (Public and Private)*

- Building the capacity of lead farmers.
- Making use of agro-dealers.
- Up-to-date training of new and current extension staff.
- Include more women for better targeting of women farmers.
- Increased funding of extension services.
- The message from extension services needs to be updated and be made consistent through better linkages with knowledge providers.

5. *Other Key Points*

- Fertilizer adulteration must be tackled: technology, regulation, enforcement.
- Blending plants are key for effective fertilizer use.
- The private sector will lead scaling–up; government enables and regulates.

Acknowledgement

The authors of this work would like to acknowledge AGRA-SHP program, Malawi Soil Health Consortium, IPNI, LUANAR and CABI for supporting preparation of the background paper and the logistics for the workshop. We greatly thank all the distinguished experts who gathered at the Livingstonia, Hotel and came up with the recommendations that are presented in chapter 6 of this publication. In particular, Dr. Pedro Sanchez, Dr. Bashir Jama and Dr. Rebbie Harawa provided the critical linkages to the government of Malawi and Donor community who received the final report and promised to make use of it to drive appropriate fertilizer use in Malawi.

References

Benin, S., J. Thurlow, X. Diao, C. McCool, F. Simtowe, (2008). Agricultural Growth and Investment Options for Poverty Reduction in Malawi. *IFPRI Discussion Paper 00794*.

Benson T, D. (1996). A geographical and economic analysis of past nitrogen response trial results for maize in Malawi. *In proceedings of the fifth Eastern and Southern Africa Regional Maize Conference, held in Arusha, Tanzania, 3-7 June, 1996. Eds Ransom et al., Maize productivity gains through research and technology dissemination. Pp191-196*.

Benson, T.D. (1997). Spatial and temporal variation in fertilizer recommendations for maize grown by smallholders in Malawi. *Pages 135-144 in Maize Commodity Team Annual Report, 1995-96. Chitedze Research Station, Lilongwe, Malawi: Ministry of Agriculture, Department of Agricultural Research*.

Benson T.D. (1999). Validating and strengthening the area-specific fertilizer recommendations for hybrid maize grown by Malawian smallholders: *A research report of the results of the nationwide 1997/98 Maize Fertilizer Recommendations Demonstration*.

Benson T., J. Kaphuka, S. Kanyanda, and R. Chinula. 2002. Malawi: An Atlas of Social Statistics. National Statistical Office, Zomba, Malawi and International Food Policy Research Institute, Washington, DC, USA.

Bolton, A., and A.J., Bennett, (1974). ODM Research Project R2415, Maize Breeding and Agronomy, General Report, Chitedze, Lilongwe, Malawi

Brown, P. and A. Young. (1966). The physical environment of Central Malawi: With Special Reference to Soils and Agriculture. Government Printer, Zomba, Malawi.

Chilimba A.D.C and Nkosi D. (2014). Development of area specific fertilizer recommendations in Malawi.

Chilimba, A.D.C. (1996). The effectiveness of universal soil extractants in detecting nutrient deficiencies in Malawi soils. *M.Sc. thesis, Crop Science Department, Bunda College of Agriculture, University of Malawi, Lilongwe, Malawi*.

Chilimba, A.D.C., Young, S.D., Black, C.R., Meacham, M.C., Lammel, J., Broadley, M.R. (2012). Agronomic biofortification of maize with selenium (Se) in Malawi. *Field Crops Research, 125:118-128*.

Chinsinga, B. (2012). The political economy of agricultural policy processes in Malawi: A case study of the fertilizer subsidy programme. *Future Agricultures Consortium Working Paper 39* (available at: http://r4d.dfid.gov.uk/PDF/Outputs/Futureagriculture/FAC_Working_Paper_039.pdf).

De Ruiter, P.C., J.C. Moore, K.B. Zwart, L.A. Bouwmann, J. Hassink, J. Bloem, J.A. De Vos, J.C.Y. Marinissen, W.A.M. Didden, G. Lebbink, and L. Brussaard. (1993). Simulation of nitrogen mineralization in the below ground food webs of two winter wheat fields. *Journal of Applied Ecology* 30: 95-106.

Dorward, A. and Chirwa, E. (2011). The agricultural input subsidy programme 2005/06 to 2008/09'. *International Journal of Agricultural Sustainability, 9(1): 232–247*.

Fairweather-Tait S., Bao Y., Broadley M., et al., (2011). Selenium in human health and disease. Antioxidants and Redox signaling, 14: 1337-1383

FAOSTAT (2011). Current world fertilizer trends and outlook to 2015. *Food and Agriculture Organization of the United Nations, Rome*.

Gilbert R.A., M.K Komwa, T.D Benson, W.D Sakala. (2002). A comparison of best-bet soil fertility technologies for maize grown by Malawian smallholders. *A Research Report of the Results of the Nationwide 1998/99 and 1999/2000 On-Farm Cropping System Verification Trial*.

IFDC (2007). Fertilizer Supply and Costs in Africa. *A Report prepared for Bill and Melinda Gates Foundation*.

IFDC, (2013). Malawi fertilizer assessment: In support of The African Fertilizer and Agribusiness partnership (AFAP) . *Accessible at www. Ifdc.org*

Jayne, T.S. and S. Jones (1997). Food Marketing and Pricing Policy in Eastern and Southern Africa: A Survey. *World Development,* 25 (9): 1505-1527.

Kabambe, V.H. and J.D.T. Kumwenda. (1995). Weed management and nitrogen rate effects on maize yield in Malawi. In: D. Jewell, S. Waddington, J. Ransom, and K. Pixley (eds.) *Maize research for stress environments*. CIMMYT, Harare, Zimbabwe.

Kamanga, B., Waddington, S., Robertson, M. & Giller, K. (2009). Risk analysis of maize-legume crop combinations with smallholder farmers varying in resource endowment in Central Malawi. *Experimental Agriculture*, 46, pp. 1-21.

Kamanga, B.C.G., (2011). Poor people and poor fields? Integrating legumes for smallholder soil fertility management in Chisepo, Central Malawi. *PhD thesis*. Wageningen University, Wageningen.

Kelly, V., Jayne, T. and E. Crawford (2005). Farmers' Demand for Fertilizer in Sub-Saharan Africa. *Draft Paper prepared for the World Bank by the Department of Agricultural Economics, Michigan State University, East Lansing*.

Kumwenda AS (1998). Soil Fertility Research for Maize-based Farming Systems in Malawi and Zimbabwe. In Waddington SR, Murwira HK, Kumwenda JDT, Tagwira F *(eds.), Soil Fertility Research for Maizebased Farming Systems in Malawi and Zimbabwe*. *Proceedings of the Soil Fert Net Results and Planning Workshop, 7-11 July 1997, Mutara, Zimbabwe. CIMMIT. pp. 263-269.*

Kumwenda, J.D.T. (1994). Fertiliser time of application (on-farm). *Maize agronomy annual report for 1993/4*. Chitedze Agricultural Research Station, Lilongwe, Malawi.

Kumwenda, J.D.T., S.R. Waddington, S.S. Snapp, R.B. Jones, and M.J. Blackie. (1997). Soil fertility management in Southern Africa, pp. 153-172. In: *D. Byerlee and C.K. Eicher (eds.), Africa's Emerging Maize Revolution*. Lynne Publishers, Boulder, CO.

Kumwenda, J.D.T., S.S. Snapp, V.H. Kabambe, A.R. Saka, and R.P. Ganunga. (1996). Effects of organic legume residues and inorganic fertilizers on maize yield in Malawi. *Target Newsletter No. 7, Soil Fertility Network for Maize-Based Farming Systems, CIMMYT, Harare, Zimbabwe*.

Ladd, J.N., and M. Amato. (1985). Nitrogen cycling in legume-cereal rotations. In B.T. Kang and J. van der Heide (eds.), *Nitrogen Management in Farming Systems in Humid and Sub-Humid Tropics*. The Netherlands: International Institute of Tropical Agriculture (IITA) and ISF. Pp. 105-127.

Maida, J.H.A. and A.R. Saka. (1986). A brief overview of Malawi's soil fertility status and crop yield response to addition of fertilizers. pp. 42-47. In Maida (ed.). *Research Highlights and Constraints to Crop Production. Proceedings of 1986 Research and Extension Workshop*. Blantyre Print and Packaging Co. Ltd.

Mcardle, W.D, Katch, F.J, Katch, V.L (2006). Exercise physiology: Energy, Nutrition & Human Performance. 6th edition.

National Statistical Office Malawi Government (2008) Enhancing Agricultural Input Use Efficiency in Malawi. A Research Report of the National Subsidy Programme Technical Support Workshop in Lilongwe, 15–16 April 2008. Department of Planning, Ministry of Agriculture, Lilongwe.

Ngwira, L., and W.G. Nhlane. (1986). Maize research in Malawi. In: J. Maida (ed.). *Research highlights and constraints to crop production, Proceedings of the Research and Extension Workshop.* Mangochi, Malawi. pp.73-80.

Saka A. and J. Chisenga. (1990). Nitrogen and water management under rainfed and irrigated conditions. In: *Nitrogen and Phosphorous Management of Field Crops in Malawi*. The Hebrew University of Jerusalem / Malawi Government.

Sakala, W.D., (1998). Nitrogen dynamics in maize/pigeonpea intercropping in Malawi. 1998 PhD Thesis. Wye College, University of London.

Sillanpaa, M. (1982). Micronutrients and nutrient status of soils: A global study. *FAO Soils Bulletin 48, FAO, Rome, Italy*.

Smale, M., and P. W. Heisey. (1997). Maize technology and productivity in Malawi. pp. 63-79. In: (Byerlee and Eicher, eds.) Africa's Emerging Maize Revolution. Lynne Reiner. Boulder, CO. pp 301.

Snapp, S.S. (1995). Improving fertilizer efficiency with small additions of high quality organic inputs. In S.R. Waddington (ed.), *Report on the First Meeting of the Network Working Group. Soil Fertility Research Network for Maize-Based Farming Systems in Selected Countries of Southern Africa*. Lilongwe, Malawi, and Harare, Zimbawe: The Rockefeller Foundation Southern Africa Agricultural Sciences Programme and CIMMYT. Pp. 60-65.

Snapp, S.S. and T. Benson. (1995). GIS to develop area-specific fertilizer recommendations in Malawi: Soil resources, yield potential and decision trees, p. 301. In: *Agronomy Abstracts. American Society of Agronomy, Madison, WI.*

Snapp S. S. (1998). Soil nutrient status of smallholder farms in Malawi. *Communications in Soil Science and Plant Analysis, 29:17-18, 2571-2588, DOI: 10.1080/00103629809370135*

Snapp, S.S., P.L. Mafongoya, and S. Waddington. (1998). Organic matter technologies to improve nutrient cycling in smallholder cropping systems of Southern Africa. *Agric. Ecosys. Environ 71: 185 - 200.*

Sommer, R, Bossio D, Desta L, Dimes J, Kihara J, Koala S, Mango N, Rodriguez D, Thierfelder C and Winowiecki L (2013) Profitable and Sustainable Nutrient Management Systems for East and Southern African Smallholder Farming Systems– Challenges and Opportunities. *A synthesis of the Eastern and Southern Africa situation in terms of past experiences, present and future opportunities in promoting nutrients use in Africa*

Swift, M.J., and P. Woomer. (1993). Organic matter and the sustainability of agricultural systems: Definition and measurement. In K. Mulongoy and R. Merckx (eds.), *Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture*. Chichester, U.K.: Wiley-Sayce. Pp. 3-18.

Tittonell, P., A. Muriuki, K.D. Shepherd, D. Mugendi, K.C. Kaizzi, J. Okeyo, L. Verchot, R. Coe, and B. Vanlauwe. (2010). The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa—A typology of smallholder farms. *Agric. Syst. 103:83–97.*

Tittonell, P., Vanlauwe, B., Leffelaar, P.A., Rowe, E.C., Giller, K.E., (2005). Exploring diversity in soil fertility management of smallholder farms in western Kenya: Heterogeneity at region and farm scale. *Agric. Ecosyst. Environ. 110, 149–165*.

Townsend, R.F. (1999). Agricultural Incentives in Sub-Saharan Africa: Policy Challenges. *World Bank Technical Paper No. 444*. Washington, DC. The World Bank.

Vanlauwe, B., P. Tittonel, and J. Mukalama. (2007). Within-farm fertility gradient affects response of maize to fertilizer application in Western Kenya. In; Batiano, A. (Eds.) *advances in Integrated soil fertility management in sub-Sahara Africa: Challenges and opportunities. 121-132.*

Venema, J.H. (1990). Land resource evaluation project. Methods of description, classification and mapping of natural regions of Malawi. *Field document No. 3. Malawi Government Ministry of Agriculture Land Husbandry Branch, United Nations Development Programme, Food and Agriculture Organization of the United Nations, Rome, Italy.*

Weil R.R and Mughogho S.K (2000). Sulfur nutrition of maize in four regions of Malawi. *Agron. J. 92:649-656.*

Wendt, J.W., R.B. Jones, and O.A. Itimu. (1994). An integrated approach to soil fertility improvement in Malawi, including agroforestry. In E.T. Craswell and J. Simpson (eds.), *Soil Fertility and Climatic Constraints in Dryland Agriculture.* ACIAR Proceedings No.54. Canberra, Australia: Australian Council for International Agricultural Research (ACIAR). Pp. 74-79.

White P. J. And Broadley M. R. (2005). Biofortifying crops with essential mineral elements. *Trends Plant Sci. 10, 586–59310.1016/j.tplants.2005.10.001*

Woomer, P.L., A. Martin, A. Albrecht, D.V.S. Resck, and H.W. Scharpenseel. (1994). The importance and management of soil organic matter in the tropics. In P.L. Woomer and M.J. Swift (eds.), *The Biological Management of Tropical Soil Fertility*. Chichester, U.K.: Wiley-Sayce. Pp.47- 80.

Zingore, S., H.K. Murwira, R.J. Delve, and K.E. Giller. (2007). Soil type, management history and current resource allocation: Three dimensions regulating variability in crop productivity on African smallholder farms. *Field Crops Research 101:296–305*

Presentations

1. Malawi Fertilizer Workshop, Objectives and Expected Outputs (Rebbie Harawa, AGRA)
2. Improving fertilizer recommendations in Malawi (Bashir Jama-AGRA)
3. Conservation agriculture for smallholder farmers in Malawi (Thiefelder et al -)-CIMMYT and Total land Care
4. The Clinton Development Initiative (CDI)/AGRA Anchor Farm Project: Key achievements, lessons, challenges
5. The Problem of current fertilizer recommendation in Malawi (Andrew T. Daudi; MVP)
6. Fertilizer tree technologies. Opportunities and Challenges in Malawi (Sileshi, GW; ICRAF)
7. Taking stock of soil research activities on key grain legumes (Ganga Rao; ICRISAT
8. The status of fertilizer recommendation in Malawi. Gaps Challenges and opportunities (Vernon Kabambe; Lilongwe University of Agriculture)
9. Fertilizer Optimization Tools (Kayuki Kaizzi, NARO)
10. Input Use in Legumes in Malawi-The N2Africa Perspective (Linus Franke; N2Africa)
11. Field soil test kit to assess soil fertility-The soil Doc (Lydia Gatere; The earth Institute Colombia)
12. Spatial predictions of crop yield responses to nutrient applications (Markus Walsh; AFSIS)
13. Pigeonpea scale out in central Malawi (NASFAM)

List of Participants

	NAME	INSTITUTION	EMAIL ADDRESS
1	Alex Verlinden	AFSIS	Alex.verlinden@afiss.na
2	Amos Ngwira	DARS	amosngwira@yahoo.com
3	Anne Carr	Private	
4	Austin Ngwira	Clinton Foundation	angwira@clintonfoundation.org
5	Bernard Kamanga		
6	Cheryl Palm	Columbia University	cpalm@ei.columbia.edu
7	David Kimani	AGRA	dkimani@agra.org
8	Dorothy Shivere	AGRA	dshivere@agra.org
9	Andrew T. Daudi	Millennium Villages Project	Andrew.daudi@millenniumpromise.org
10	David Kamachacha	Mtalimanja Holdings /Pentecostal Life University	kamachachadavid@yahoo.com
11	Ganga Rao N.	ICRISAT	n.gangarao@cgiar.org
12	Geoffrey Kananji	AGRA	gkananji@agra.org
13	Horace Nyaka		
14	James Mutegi	IPNI	jmutegi@ipni.net
15	Joyce Njoloma	ICRAF	jnjoloma@cgiar.org
16	Kayuki Kaizzi	CABI/NARO	kckaizzi@gmail.com
17	Linus Franke	UFS	frankeac@ufs.ac.za
18	Lydia Wairegi	CABI	l.wairegi@cabi.org
19	Lydiah Gatere	Columbia University	Lwg2112@columbia.edu
20	Mulemia Maina	AGRA	mmaina@agra.org
21	Pedro A Sanchez	Columbia University	Psanchez@ei.colombia.edu
22	Phelire Nkhoma		phelirenkhoma@yahoo.com
23	Rebbie Harawa	AGRA	rharawa@agra.org
24	Richard Jones	AGRA	rjones@agra.org
25	Richard Mkandawire	AFAP	mkwandawire@afap-partnership.org
26	Samu Phiri	NASFAM	samudickson@yahoo.com
27	Shamie Zingore	IPNI	szingore@ipni.net
28	Sileshi Weldesemayat	Consultant, Zambia	sileshigw@gmail.com
29	Stanlee Juma	Ex-Agris Africa	sjuma@exagrisafrica.com
30	Stephen Carr	Private	scarr@sdnp.org.mw
31	Veria Kumwenda-Laemmle	Fertlizer Association	veria.kumwenda@gmail.com
32	Vernon Kabambe	Luanar	kabambev@yahoo.com
33	Wezi Mhango	LUANAR Bunda College	Wezzi2002@yahoo.com
34	Wilson Makumba	DARS	wilk.makumba@gmail.com

IPNI International Plant Nutrition Institute

Soil Health Consortium of Malawi

www.cabi.org

AGRA Growing Africa's Agriculture