



STATUS OF INTEGRATED SOIL FERTILITY MANAGEMENT (ISFM) IN SOUTHWESTERN NIGERIA

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ABSTRACT

Article History

Received: 31 August 2016
Revised: 14 January 2017
Accepted: 16 February 2017
Published: 8 March 2017

Keywords

Integrated soil fertility management
Organic resources
Soil degradation
Sustainable land use
Local adaptations
Improved crop varieties

The soils of South western Nigeria are rapidly degrading due to nutrient mining, soil loss, inappropriate land use, low inherent soil fertility coupled with adverse effects of climate change. These have resulted to persistent low yields and farmers' poverty. The current farming systems have failed to improve continuous decline in crop production. There is need for integrated approach that involves mineral fertilizer, organic resources, and improved crop varieties with sound agronomic practices if the region will be able to feed its population of over 35 million people. Integrated Soil Fertility Management (ISFM) is an all-encompassing resource management technique that embraces the use of good planting materials, with appropriate organic and/or inorganic fertilizer application or their integrated use. It also entails adapting the various combinations of the ISFM components to local conditions which by implication means site specific management. There is lack of coordinated information about the components of ISFM being used in SWN and most stakeholders have not appreciated the importance of integrated approach. This paper is therefore put forward to review the status of Integrated Soil Fertility Management in South western Nigeria in order to identify knowledge gap for sustainable crop production in the region.

Contribution/ Originality: This study contributes in existing literature on integrated soil fertility management for sustainable crop production in southwestern Nigeria. The study also harmonizes research findings about ISFM thereby making information available for researchers, policy makers, extension agents and other stakeholders about ISFM protocols. It aids in identifying knowledge gaps for intervention.

1. INTRODUCTION

There is lack of coordinated information about the status of ISFM in Southwestern Nigeria (SWN). Several studies have been carried out about components of ISFM but optimal and sustainable crop production have not been attained by farmers. The aim of this paper therefore is to review the level of ISFM integration into production systems, identify constraints and knowledge gap and make recommendation for sustainable increase in the quantity

and quality of food. South western Nigeria is situated within latitudes $4^{\circ}00'N$ and $7^{\circ}00'N$ and longitudes $2^{\circ}30'E$ and $7^{\circ}00'E$ which comprises of the following states: Oyo, Ogun, Ekiti, Osun, Ondo and Lagos states. The area is underlain by basement complex rocks and to the south is a thick bed of sedimentary formation. The geomorphology shows a variety of landforms starting from the coast northwards: the plains, the undulating areas and the highlands. The parent rocks resulted to soils of heterogeneous properties such that within an hectare of land different units of soil may be found which has implication for soil management. The climate is divided into dry and wet season which is characteristic of the tropics. Mean annual rainfall is highest (between 2.032 and 4.064mm) in the coastal areas. In the south of the area mean daily temperature ranges from $28^{\circ}C$ to $30^{\circ}C$ and ranges from $32^{\circ}C$ to $33^{\circ}C$ in the northern sector. The high temperature and intensive rainfall make the soil susceptible to erosion coupled with high rate of mineralization of organic matter, hence the soils have low organic C and inherently thin and fragile top soils (Omotayo and Chukwuka, 2009)



Figure-1. Location map of South Western Nigeria

Much of the natural vegetation of the area had been altered by cultivation, overgrazing and animal husbandry and bush fire over a long period of time. Hence, direct impact of climatic factors on soils are of great concern to effective management. Therefore to save the thin layer of top soils in these area there is a need for urgent popularization of measures that can protect the soils.

1.1. Soil Characteristics That Affects Soil Fertility

Compared to other areas in Nigeria, a large proportion of soil in south western has been under cultivation for a long period of time with little attention paid to their management hence, the soils are degraded and exhibits a variety of constraints, among which are nutrient deficiency, low organic matter, moisture stress, and high erodibility. The nature of the soil and its' properties in terms of its compactness, the soil structure and texture are determinants of the soil fertility in south western Nigeria (Ande *et al.*, 2008). The type of clay in soils of southwestern Nigeria are predominantly kaolinites (Ajayi and Agagu, 1981) and are characteristically low in CEC (Oluwatosin *et al.*, 2008). Soils in the derived savanna area have high content of sandy soils are also prominent in the region which is characterized by excessive leaching of plant nutrients due to the action of percolating water obeying the force of gravity; otherwise called gravitational water. Thus the leached plant nutrients may no longer be available for the plants to absorb. It has low capillarity force due to the large pore space. It is as a result of this that the soil is incapable of allowing soil water to rise up to the subsoil level, where it could be available for crop plants to absorb during the dry season. Thus, this condition aggravates moisture stress in the cropping season which is now prevalent in the

region due to climatic variability. There is need for fertility management practices that can adapt to climatic variability for optimal crop yield.

Soil fertility is dependent upon the continued replenishment of nutrients and organic matter that is depleted each cropping season. In southwestern Nigeria, due to high temperature there is high rate of mineralization of organic matter, hence once soils are opened there is a continuous depletion of the SOM. Organic matter cannot be built up permanently because it continually decomposes. Therefore building up and maintaining soil organic matter levels must be an on going process. To ensure continued soil fertility, organic matter, in the form of green manure, compost, crop residues and similar materials should be incorporated into the soil after harvest. These approaches are not effectively integrated into the farming system in the region. Hence low soil quality and low yields characterized the production systems.

Soil must not only be capable of storing nutrients but it must also be able to transfer these nutrients to the root surface for uptake by the plant. Unhealthy plants result from unhealthy soil. Cation exchange capacity of a soil is important because exchangeable cations such as calcium, magnesium, and potassium are readily available for plant uptake and cations adsorbed to exchange sites are more resistant to leaching, or downward movement in soils with water. Hence CEC is one of the soil quality parameters that determines fitness of a soil for a specific use. Low CEC will translate to soils with low nutrients like K, Ca and Mg. Soils of southwestern Nigeria are generally low in CEC but with high percent base saturation (Oluwatosin *et al.*, 2010; Institute of Agricultural Research and Training (IAR&T) Soil Survey Report, 2012). Nutrient mining characterizes the region, thus CEC are easily depleted further aggravating soil quality.

Soil pH has a profound influence on plant growth. Soils of southwestern Nigeria are predominantly moderately to slightly acidic. This has implication on fertilizer use in that fertilizer that increase soil acidity like ammonium sulphate is no longer recommended to farmers. The acidic nature of the soils influences availability of macro and micro nutrients.

The solubility of P is influenced by the soil pH. Phosphorus is most available in slightly acid to slightly alkaline soils, while all essential micronutrients, except molybdenum, become more available with decreasing pH. Aluminum, manganese, and even iron can become sufficiently soluble at $\text{pH} < 5.5$ to become toxic to plants. Hence P content in soils of south western Nigeria are low to moderate. Thus, researches on P bio-solubilisation are being carried out to make P more available in the soils of Southwestern Nigeria. Bacteria which are important mediators of numerous nutrient transformation mechanisms in soils generally tend to be most active in slightly acid to alkaline conditions. Maintain good pH is paramount to soil health and successful crop production.

Nitrogen content of southwestern varies between low and moderate depending on intensity of land use, denitrification, low organic matter and poor soil structure. Incorporation of organic matter and nutrients from organic fertilizers will stimulate microbial activity and significantly improve the N.P.K. availability in the region. The need to incorporate organic residues into these soils is the panacea to sustainable crop production and has not been explored satisfactorily to increase yield by smallholder farmers significantly.

1.2. Overview of Soil Fertility Management

1.2.1. Farmers' Traditional Practices

The farmers' practices for soil fertility regeneration and nutrient cycling within agricultural areas in 20th century were predominantly traditional shifting cultivation system, where a few years of cultivation are followed by very long fallow periods. Fallowing is so long (more than 10 years) that trees and bushes grow up again to form a secondary forest. In this way, fertility of the soil is completely restored after it has been cropped to low fertility status. As competition among farmers has risen in terms of hectareage of lands, fallow periods became shorter, and shifting cultivation gave way to rotational bush fallowing. Hence, the time that the land lies fallow exceeds the time the land is put under cultivation. With further shortening of the fallow periods, the land-use system developed into a degraded

bush fallow system. In this way, fallow periods are too short to fully restore soil fertility. This however, led to large deforestation and increasing encroachment on marginal lands, where the resilience ability of the soil is limited (Lal, 1995). As the traditional shifting cultivation and bush fallow systems pave way to continuous cultivation in the 21st century, because of demographic pressure, the detrimental effects of soil degradation become prominent. The need for increase crop production led to introduction of mineral fertilizers to farmers. However, the degradation processes have progressed thus far such that only application of mineral fertilizer is not sufficient to bring good harvest. Hence, incorporation of organic residues into farming system was introduced to improve soil health and quality (Adediran *et al.*, 1995; Akande *et al.*, 2006; Ande *et al.*, 2010). Despite the fact that sustainable crop production is only feasible by use of mineral and organic fertilizers, the use of these components are still low. Fertilizer use in SWN is put at about 10-15kg N per hectare, while in other part of the country fertilizer use is put at 20kg N on the average. Nigeria lags behind countries like South Africa and Egypt that use over 100kg N per hectare. Thus the average yield per hectare of maize in South western Nigeria is about 1.5 – 2 tons/hectare, but in few commercial farms where fertilizer up to 250kg of NPK is being used, yield as high as 4 tons/hectare are recorded. The more fertilizer employed in growing crops, the higher the yield, other things being equal.

1.2.2. Trends in Integrated Soil Fertility Management

Although, knowledge of farmers, extension and research about integrated approach is increasing, it has not attained complete ISFM especially in local adaptations and fertilizer use. The current level in the use of fertilizer and organic resources was not based on recommendations from research but farmers use fertilizers based on purchasing power and also availability of the products in the region.

Application of chemical fertilizers constitutes a practice by farmers in attempt to correct the deficiencies of nutrient elements. The case of significant increase in fertilizer consumption and increase in crop production in south western Nigeria is obvious from all the researches carried out so far but small holders' farmers cannot afford 120kg/ha N of NPK (20-10-10) recommended for maize production on low fertility soils. While 60kg/ha N of NPK (20-10-10) is recommended for soils of moderate fertility status. However, about 50-75kg/ha of NPK (15-10-10) and urea fertilizer is the usual application due to high cost of fertilizer. A 50kg bag of NPK (15-10-10) and urea fertilizer costs about N6000 each. Other constraints include none availability at right time needed for crop production.

Based on the fact that the soils are acidic as a result of their parent materials, weathering and leaching (Obi and Ekperigin, 2001) the continuous use of acid-forming fertilizers like urea will contribute significantly to soil acidity if use is intensified. Thus, the need to focus on alternative sources of nutrients that will be less damaging to the soil becomes imperative. Many workers have suggested the use of organic manures.

Use of fertilizer and organic resources has been well popularized, however holistic view with improved crop varieties and site specific soil management were not usually considered together. This is evident from research work where ISFM components were evaluated separated without integrating other agronomic practices. There is need to create more awareness about synergetic benefits of integrated approach. Researches carried out also revealed increased and more efficient use of mineral fertilizers and the decrease of fertilizer subsidies amidst declining farmers' capabilities to procure it and other external inputs (Lawal *et al.*, 2007; Lawal and Ayoola, 2008; Lawal *et al.*, 2012). Farmers' are favourably disposed to organic fertilizer technology in terms of usage, yield and output. However, they were unfavourably disposed to the technology in terms of transportation and cost of technology. The available organic materials include poultry dung, crop residues, household waste, products from crop processing like cassava peels, herbs with low N:C ratio. Socio-economic variables (years of education and extension visit) had significant relationship with farmers' knowledge of organic fertilizer. Lawal and Ayoola (2008) highlighted the need for farmers groups and cooperative societies for disseminating and diffusing of knowledge on organic fertilizer. It was found that most farmers required training in the gathering and use of organic materials for composting. The study also established that farmer-specific attributes such as knowledge of compost making, education level, livestock rearing,

gender and availability of compost materials are important determinants in farmers' probable use of compost in crop production. Hence there is need to intensify training of farmers on compost production at farm levels using available materials. The need for use of locally available resources to ensure the growth and sustainability of dry season vegetable farming for improved food security has been established (Ayoola *et al.*, 2008). The immediate solution to increase organic inputs use is to organize on-farm training for farmers on organic fertilizer production using farmers field schools and farmers' organization. Long term solution should be through public-private partnership in organic fertilizer production and distribution and gender sensitive extension delivery system in organic fertilizer usage (Lawal *et al.*, 2012). Another constraint limiting optimum crop production in farmers' field is low population density of crops on the field and inadequate use of fertilizer contributed to low yield (Ayoola and Lawal, 2011). Hence, there is need for farmers to adopt good agronomic practices.

If all soil fertility management strategies including sound agronomic practices were considered holistically by packaging relevant technologies together based on ecology, farmers' frustration of tackling another problem when one is being solved will be reduced. Example is cessation of rainfall in the region during the crop season in 2015 due to climatic variability. Hence the need to integrate water harvesting techniques into farming system to avoid crop failure inspite of other appropriate inputs and sound agronomic practices. Understanding of ISFM will definitely solve this problem to enhance sustainable crop production and farmers' livelihood.

2. INTEGRATED SOIL FERTILITY MANAGEMENT

Integrated Soil Fertility Management (ISFM) is defined by Africa Soil Health Consortium as 'A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at optimizing agronomic use efficiency of the applied nutrients and improving crop productivity (Vanlauwe *et al.*, 2011). All inputs need to be managed following sound agronomic and economic principles.' The definition implies that ISFM is an all-encompassing resource management technique that embraces the use of good planting materials, with appropriate organic and/or inorganic fertilizer application or their integrated use.

It also entails adapting the various combinations of the ISFM components to local conditions. This might mean local climatic or soil conditions, this entails good agronomic practices in terms of planting dates, planting densities, soil-water and nutrient management and weeding that are essential to ensure efficient use of scarce nutrient resources. By implication, it covers the use of appropriate soil, nutrient and water management techniques tenable in the environment where it is limiting (site specific management). For example, an appropriate ISFM practise for a farm ravaged by soil erosion, with low crop yield might be the use of good agronomic practices, improved crop variety with good and appropriate fertilizer and manure application. These combinations will however, not be sustainable until it is married with an effective erosion management practice in the locality, e.g. cultivating across the slope or the use of cover crops. Therefore, complete ISFM is the solution to effective management of soil fertility in tropical sub-humid soils. The main objective of ISFM particularly in sub-Saharan Africa (SSA), where there is constant increase in human population, is increased productivity in farming systems (i.e. increased crop production or yield intensification). This will translate to sustainable increase in food, feed, fibre and fuel production without compromising the health of the soil resource. Yield intensification is usually concerned with increasing the yield of crops but may also involve increasing the *number* of crops grown in each field each year. In addition to the sparing of land for other uses, yield intensification has benefits of increasing returns to labour (i.e., reducing the drudgery of intensive labour investment for little return), and increasing farmers' food self-sufficiency and incomes.

The issues affecting soil health and productivity in the sub-humid tropical regions are similar and range from low inherent soil nutrient reserves, low use of external nutrient inputs, nutrient mining, climate variability coupled with aggressive rainfall pattern have resulted to low crop productivity. Crop residues are not usually incorporated into the soil. Hence there is decrease in soil organic matter reserves. This has limited various functions that enhance the

efficiency with which water and nutrients are used by crops. The local crop varieties commonly grown have low demand for nutrients and the efficiency of conversion of nutrients and water to yield is also low. The relatively steep slopes and minimal use of erosion-control measures also contribute to significant soil losses (Vanlauwe *et al.*, 2011). It has been observed recently that moisture stress has become a major threat to food security in South western Nigeria due to erratic rainfall pattern and dry spell during the cropping season. Soil fertility degradation has been described as the second most important constraint to food security in Africa which is also a major constraint to sustainable soil production in SWN. Despite proposals for a diversity of solutions and the investment of time and resources by a wide range of institutions, soil fertility decline continues to prove to be a substantially intransigent problem. Improper management due to indiscriminate land use without soil testing has exacerbated this problem to an alarming rate. The population is thus trapped in a poverty cycle between land degradation, and the lack of resources and knowledge to generate adequate income and opportunities to overcome vicious decline in soil quality.

Plant production in natural ecosystems such as rain fed agriculture of SWN primarily depends on nutrient recycling and biological fixation of atmospheric nitrogen. Thus, sustainable crop production on these soils must strongly emphasize inorganic and organic combination. The choice of nutrient management strategies depends not only upon using crops that are adapted to a particular ecology and cropping system, but also upon the available resources at the farm. The production system in SWN should be based on integrated soil nutrient management using improved old and new methods of nutrient management into ecologically sound and economically viable farming systems that utilize fortified organic fertilizer in a judicious and efficient way so as to maximize crop production and maintain soil health. There is also need for integrated soil nutrient management such as improved short fallow with legume (e.g. *mucuna pruriens/Vigna Unquiculata*) in cropping system (Ande and Onajobi, 2009) or with high biomass plant (*Chromolaena odoratum*) to revitalize degraded soils that are almost unresponsive to fertilizer. These approaches are yet to be well understood by stakeholders in the region which call for more training of farmers by soil extensionists. The problems in the region is compounded by haphazard and sparse use of inputs, wrong crop combinations, bad agronomic practices and inability to cope with climate change which have further increased farmers poverty due to consistent low yields. Without sustainable increase in crop production, farmers living standards in the SWN will remain low. Hence, farmers need to know what the quality of their soil is in order to make proper investment decisions. They also need to have information on and access to the technologies that are suited for their specific situation.

3. OPPORTUNITY FOR ISFM IN S.W. NIGERIA

3.1. Use of Improved Crop Varieties in Integrated Soil Fertility Management in S.W Nigeria

Improved crop varieties have been very helpful in solving some soils related problems in crop production. These have also offered some solutions to problems posed by pest and diseases. Improved crop varieties have the capacity to enhance yields due to reduction of biotic and abiotic stresses of the production environment such as drought, flood, low Nitrogen, acid soils, thick cloud cover, crop lodging (occasioned by strong wind). There is need to encourage more use of improved weed and pest resistant genotypes, varieties with good mineral up-take, low nitrogen tolerant, high nodulation species as well as plant with suitable architecture and high biomass that can conserve moisture, soil nutrient and prevent direct sun penetration into the soil. In the same vein, for sustainable soil fertility and reduction of erosion, there is need to promote plants that allow crop mixture and intercrop such as cereals-legume based intercrop.

Improved varieties have been bred in SWN to mitigate problems related to plant pest and diseases, unfavourable agro-ecologic conditions, and for limited nutrient availability. Varieties with adaptation to striga endemic soil had been developed and released in order to put land, abandoned due to striga, to use (Olakojo, 2004). Crop varieties have been bred to exploit yield potential of different agro-ecologies with variation in soil characters, soil fertility, and nutrient composition. Many of these maize varieties thrive under low Nitrogen concentration with good yield (Olakojo *et al.*, 2005). Maize varieties for good stability had also been reported by (Ogunbodede *et al.*, 2001; Olakojo

and Iken, 2001). In the same vein, maize varieties with adaptation or resistance to acid soil, low nitrogen and pest/disease (stem borer, streak, blight and downy mildew) resistance had been released by IITA and other research institutes in Nigeria waiting for mass promotion, dissemination and adoption. Example of such varieties which are resistant to disease infestation include DMRSR –Y, TZMSR-W , DMRLSR-W and SWAN-1SR and are also high yielding compared to the local varieties. In trials involving improved crop varieties the controls (without fertilizers) gave yields of up to 3000kg/ha as compared with yields from local varieties of 800-1500kg/ha (Figure 2).

There is gradual increase in awareness of importance of improved varieties by farmers, however there is limited channels for sourcing for the seeds. The Institute of Agricultural Research and

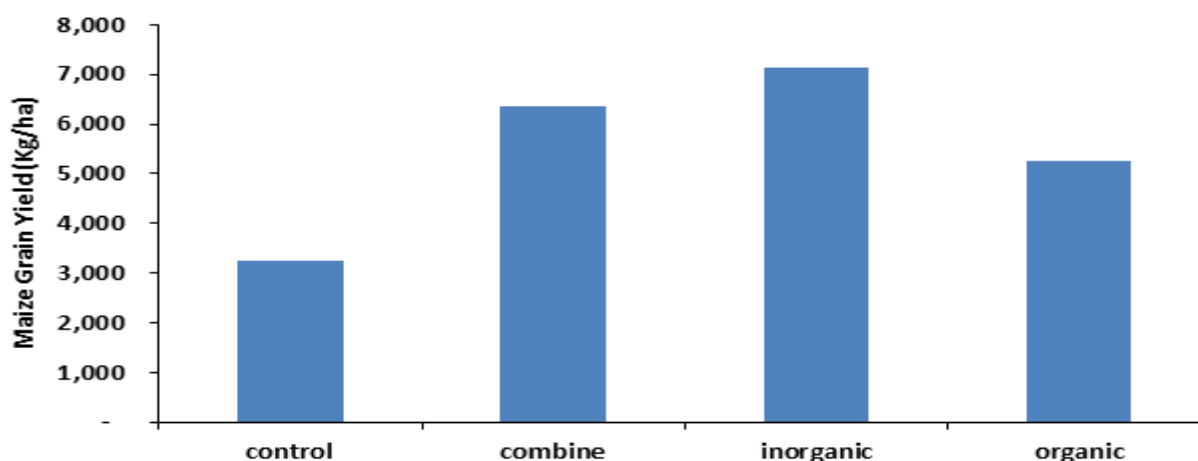


Figure-2. Maximum grain yields recorded for ISFM trials

[Source: NgSHC (South)]

Training has mandate for farming system research in SWN has established Research Extension Farming system Input Linkage System (REFILS) to transfer technologies and improved seeds to farmers in the region but funding of extension is poor. There is also need for multiplication of seed of the improved crop varieties developed and released. The distribution channels of improved seeds should be improved such that seeds are available close to farm gates. Moreover, poor extension service delivery system has hindered technology transfer. This is due low extensionist to farm family ratio of 1:7000, poor mobility, irregular training and workshop for extension agents, poor remuneration and poor general funding of extension. More research institutes with mandates for different crops should integrate sound extension activities to upscale technologies developed. There is need to reposition extension service delivery through proper trainings of stakeholders, researchers-extensionists-agro-dealers partnership in technology transfer, increase accessibility to improved seeds by including capable farmers as part of the agro-dealers and adequate funding.

3.2. Fertilizers

Fertilizers in the broadest sense are products that improve the levels of available plant nutrients and/or the chemical and physical properties of soil, thereby directly or indirectly enhancing plant growth, yield, and quality (Ullmann's Agrochemicals, 2007). Fertilizer application is a major aspect of crop production. This is also prominent in ISFM framework.

3.2.1. Mineral Fertilizers

Researches in the region has shown abundant evidences that fertilizer can improve yield of arable crops significantly (Adediran and Banjoko, 2003). Granulated urea was observed as a better choice of nitrogen fertilizer. Extension farmers in Oke- Ogun in Oyo state reported that application of SSP can double cowpea yield in the area (IAR&T REFILS, 2015). However, availability of fertilizers are limited, leading to inaccessibility in southwestern

Nigeria. In spite of awareness of importance of fertilizer, usage is still very low among smallholder farmers. Most farmers apply fertilizer without soil test, quantity applied is based on what they can afford. Despite research on fertilizer use, farmers still use fertilizer indiscriminately. Low rate of application due to non availability and high cost has hindered manifestation of gains from fertilizer use. Hence response is very low on degraded soils which characterized SWN. Reports from an IAR&T experiment on degraded soils revealed yield of 1.73 to 2.16t/ha for maize (SWAN-1SR) gave three cropping seasons with application of 300kg/ha/yr of NPK 20-10-10 (i.e 120kg N/ha) on degraded soils in SWN. In some cases average yield was reduced to 0.88t/ha in the late season with influence of moisture stress. In spite of the maximum dose of fertilizer the SWAN-1SR could not attain its genetic potential of about 4tons/ha (IAR&T Land Use Report, 2015). Farmers in SWN use about 50kg-75kg/ha/yr NPK 20-10-10 (i.e 10-15kg NPK 20-10-10/ha) hence yield of maize (SWAN-1SR) is usually between 1-1.5t/ha. How can low input farming system translate to optimum yield? This can be achieved by incorporation of appropriate cropping systems (such as cereal/legume intercrop) that can enhance soil fertility, site specific management, high yielding crop varieties and climate smart practices (e.g. supplemental irrigation) to attain agronomic efficiency. The response to fertilizer application on degraded soils is low due to loss of surface soils by erosion, light texture and low organic matter content. Hence, total dependence on inorganic fertilizers is not the the panacea to soil management and crop productivity problems in SWN due to land degradation. Associated problems which usually occur with continuous land use (or with mineral fertilizer) in the region include reduction of soil organic matter, increased soil acidity, degradation of soil physical properties and increased soil erosion (Ojeniyi, 2002). This was also confirmed on Alfisols in Ibadan that have been under cultivation for more than 30 years (Ande and Onajobi, 2009). Therefore in order to improve soil response to fertilizers, combination of mineral fertilizer and organic fertilizer have proved to be more effective.

3.2.2. Organic Resources

The reality that mineral fertilizer supply nutrients but cannot improve other soil quality necessary for sustainable use became clear as soil degradation reduces soil quality. Hence there is need for a form of fertilizer that does not only supply nutrients but enhances other soil parameters needed for good crop performance. Hence the introduction of compost from various organic waste materials. Composting is an age long practice for the biological conversion of organic waste to a humus-like substance which can enhance physical, chemical and biological soil properties. The role of compost in reducing bulk density and increasing total porosity to improve soil structure has been well reported in SWN (Adeyemo and Agele, 2010; Osunsanya, 2010). Composting of Organic waste reduces the bulkiness of the materials required for application; improves soil organic matter, physical properties and microbial activities which in turn improves its nutritional value and enhances better nutrient uptake by crop (Adediran *et al.*, 1995). The advantages of utilizing compost reported in SWN include its effectiveness, readily available organic materials, improved organic matter content, source of micro and macro nutrient and greater nutrient retention, easy to use, and desirable residual effect in the soil (Ande *et al.*, 2010; Babalola *et al.*, 2012). Other organic wastes that compared well with mineral fertilizer or used in combination that significantly increase yield, increase P availability and general soil quality include feather meal, rock phosphate and bone meal (Akande *et al.*, 2006; AyanfeOluwa and AdeOluwa, 2012). In spite of these enormous benefits use of organic waste is not yet popular except at few farmsteads. Major challenges for composting is length of time for production, labour, quantity of available resources and the need to have knowledge of how to produce it. Research activities to reduce time taken to produce compost are proving successful. Passively Aerated Composting Technique (PACT) takes six weeks while effort to reduce it further to three weeks by addition of micro-organisms has continued in IAR&T.

3.2.3. Bio-Fertilizers

For more than two decades now, investigations in SWN have also increasingly revealed the role of biofertilizer (symbionts) like arbuscular mycorrhiza fungi and Rhizobium with leguminous plants and they have been noted for guaranteeing the availability of plant nutrients in soil, enhance root absorption of the nutrients and increasing crop yield (Daramola and Taiwo, 1997; Taiwo and Adegbite, 2001) even in the absence of inorganic fertilizers (Taiwo *et al.*, 2001). I.A.R.&T is currently undergoing more researches in this area with focus on promoting bacteria that have abilities to make different nutrients available (nitrogen fixing, phosphorus solubilisation and potassium solubilisation) with phytohormone producing abilities that will be beneficial to both leguminous and non-leguminous plants. The technologies have not been developed enough to be outscaled except rhizobium inoculants. There is need to for industrial packaging to be used as micro doses to enhance adoption by farmers.

Generally, these technologies have not been used significantly for crop production by farmers. Hence all the benefits are not yet realized due to many constraints limiting upscaling, adoption and adaptation. Lack of simple and low-cost input technology for organic fertilizer production has hindered adoption. The existing technologies being evaluated in the country have not been promoted by widespread assessment to facilitate adoption. There is poor general perception and awareness of organic fertilizers in south west Nigeria. Difficulty in identifying a product as fit for its intended purpose and lack of guidelines, standards, and certification scheme on agricultural wastes recycling remain obstacles to farm wastes recycling in the country. Organic fertilizer production is highly laborious for farmers and needs high quantities of materials for the production. Organic materials such as animal dung used to be free but now one ton costs about N10,000. This an indication that there is an increase in appreciation of organic wastes as fertilizers. There is need to stimulate the production of organic fertilizers as a business rather than subsidizing alone. More trainings and improvement of extension delivery by government organization are needed since these technologies scarcely get to the stakeholders like farmers to achieve sustainable increase in crop production. IAR&T has conducted such trainings for farmers where soil survey were carried out, but lack of fund has limited such trainings. WASHC through Nigeria South West Soil Health Consortium has trained about 60 stakeholders in 2015 comprising scientists and soil extensionists from Agricultural Development Programme from six states in SWN about components of ISFM. Such trainings are essential to move ISFM forward. There is lack of communication between researcher and policy makers or the government. Moreover extension agents are not usually carried along hence most technologies ends on the shelf after publications. There in need for appropriate funding of extension programme by government if soils will be secured for generation next.

3.2.4. Complementary Use of Chemical and Organic Fertilizer

All attempts to maintain continuous crop production with chemical fertilizers alone in the tropics have failed Ojeniyi (2000) due to structural break down of soils and loss of inherent thin surface horizons under intensive rainfall and tillage practices. Moreover, due to slow release of nutrients from organic manures, farmers could not obtain optimum yield from sole use of OM. Hence, combined use of organic and inorganic fertilizers has been advocated for sustainable soil productivity under intensive continuous cultivation in SWN (Adepetu, 1997). Studies carried out in the region (Ojeniyi and Adeniyi, 1999; Makinde and Ayoola, 2012; Senjobi *et al.*, 2012) showed that cultivation with complementary use organic and inorganic fertilizers did not only give a comparable yields in arable crops and Jute as inorganic fertilizer but higher soil quality was also recorded. This approach has been used to increase yield on degraded soils (Ande *et al.*, 2010) where surface horizons have been eroded. It has also proved effective in improvement of sandy soil structure, water holding capacity and nutrient retention (Senjobi *et al.*, 2013).

However application of this technology is very low among farmers. Generally, the non-adoption or low adoption of most of these proven technologies might not be unconnected with the high cost, technicality involved, adaptability and poor technology transfer (Babalola *et al.*, 2005). There is a need for more strategic extension methods to enhance uptake by farmers. Production of organic fertilizer generally is cumbersome, time consuming, needed in high quantity

and there is need for technical know how, hence there is a need for rapid production which farmers may not be able to combine with other farm activities. Moreover, some animal dung (e.g swine slurry) contain other elements like Sulfur which have been reported to boost maize production significantly. Soil quality in SWN is characterized majorly with thin surface horizon, low organic matter and low CEC, and thus need urgent improvement with fortified organic matter.

Therefore there is an urgent need on appropriate strategies to get this technology to farmers, commercializing, and drawing the attention of government to adopt it as part of policy in fertilize use and formulation. The database developed by NgSHC South on trials that involved ISFM shows that inorganic fertilizers gave the highest yield in maize trials followed by complementary use of inorganic and organic fertilizers (Figure 2). However, the residual effects of organic fertilizers in structural improvement of soils, organic matter built up and better water use efficiency resulted in comparable yields with inorganic fertilizers which make the complementary use the best recommendation for ISFM.

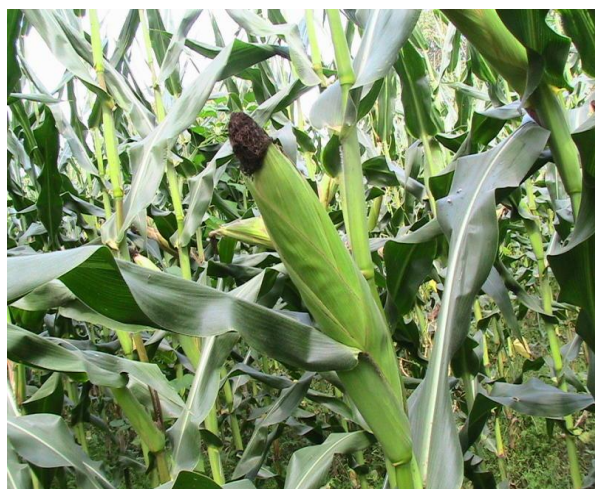


Figure 3. Effect of ISFM on Maize growth
Source: IAR&T Experimental plot



Figure 4. Effect of poor soil fertility management on maize growth
Source: www.cyberpid.org

4. ADAPTATION TO LOCAL CONDITIONS

The spatial variation in terrain characteristics (e.g. slope, landscape position etc.), soil properties (soil depth, fertility, gravel content, texture etc.) cannot be over emphasized since it is an important aspect in soil fertility management studies. The increasing rate of soil degradation owing to inappropriate land use calls for more attention especially on land capability and suitability studies. Soil fertility status is generally low in southwestern Nigeria and most soils cannot produce optimally without fertilization except newly opened vegetation areas. The area also has variable terrain characteristics. The landform is basically undulating with slope often varying from 2- 8% hence negative impacts of wrong tillage practices and intensive rainfall have resulted to loss of surface soils. Thus minimum tillage has proved effective in curtailing soil and nutrient loss by leaching and erosion if sufficient ground cover could be maintained (Are *et al.*, 2012). Farming system is basically rain-fed thus erratic rainfall due to climatic variability must be addressed to increase agronomic efficiency of inputs for increased crop yields by smallholders' farmers. Farmers were able to increase crop production periods when micro-check dams were integrated into their farming system in the derived savanna of southwestern Nigeria (Oke *et al.*, 2015). The soils also have variable surface texture and are moderate to slightly acidic. Management practices that reduce soil acidity such as introduction of derivatives from lime stone and organic residues increased yields of arable crops significantly and reduced amount of P needed for optimal yields in the region (Akande *et al.*, 2005; Oluwatoyinbo *et al.*, 2005). Moreover, heterogeneity of the soils is such that within an hectare of soils two to three soil units may be encountered that may need different management practices for sustainable use (Ande *et al.*, 2014). Intensively managed soils based on soil

testing is necessary to cope with heterogeneity of soils for sustainable crop production (IAR&T, 2012). Hence soil sampling and management practices should be done in context of the complexity of soil variability. There is also need for appropriate crop combinations (cereal/legumes; cassava/legumes) based on site characteristics and improved germplasm to tackle nutrient mining and protect soils from direct impact of climatic factors. The Agricultural Development Programme (ADP) in some part of Osun state under derived savanna ecology reported that cowpea-maize rotation resulted to higher yield of maize with little inputs due to nitrogen fixing ability of the legume (IAR&T REFILS, 2015). Use of legumes in farming system need to be promoted for sustainable crop production due to its benefits in reducing costs of inputs such as fertilizers and improvement of soil organic matter when its residues are incorporated into the soil. Hence, it can enhance the coping capacity of smallholder's farmers in adapting to ISFM. Major components that lead to better soil fertility, crop production and increase agronomic efficiency within ecological, social and economic situations must be identified and integrated under ISFM as appropriate to each cropping system and farming conditions

5. STRATEGIES TO STIMULATE ISFM FOR SUSTAINABLE USE OF LAND RESOURCES

Land should be used based on its suitability for crop production. In order to determine the suitability of a given soil for crop production, soil testing must be carried out to make appropriate recommendation. Development of soil testing centers within close reach of the farmers will enable them test the nutrient status of their soil for appropriate fertilizer application and application rate. Farmers and extension agents have also advocated for testing kits and soil doctor for quick soil nutrient evaluation. Agbede (2009) published some critical levels of soil nutrients useful in southwestern Nigeria and this has been used for interpretation of soil attribute data. Therefore, where the limiting nutrients are identified, the deficiency can be addressed by the application of combination of inorganic and manure for the additional nutrients that are not in the fertilizer.

Improper use of fertilizer have discouraged some farmers from using fertilizer (Agboola and Unamena, 1989). Once the farmers are getting poor response to the fertilizer use they will not be encouraged to using it further. So we should not indiscriminately promote the use of fertilizers but rather a more integrated approach that will assure the proper response to fertilizer application. This will require information on the soil, which can be obtained through soil testing and sound agronomic practices.

To stimulate ISFM practices there should be fertilizer recommendation for specific cropping system based on peculiarity of site. Improvement of extension services is very paramount to up-scale and increase adoption rate of fertilizer use.

Farmers in general are very poorly informed about the different aspects of ISFM because of lack of information/extension materials and information campaign. Farmers guide need to be developed to simplify technicalities of some of the technologies that are not well understood by farmers. Better communication of technologies can be achieved by producing the guides in their local dialects.

There is need to create awareness among policy makers and government agents the need for clear and stable policy on fertilizer use and other major components of ISFM. Perception of farmers generally on cropping system is evasive. Increase efforts to train farmers through on-farm demonstration farm will drive technologies more effectively. Dissemination of technologies is however poor because of the extension harm of the government lack resources to scale out the technologies due to poor funding.

6. GOVERNMENT POLICY ON FERTILIZER USE

Nigerian farmers have been facing problem of access to fertilizer. The universal fertilizer subsidy and the voucher system have also not been successful all the while. Furthermore there are problems in making fertilizers available to farmers in a timely manner. The government is trying to attend to these problems and has therefore launched Growth Enhancement Support System to attend to fertilizer distribution and usage in Nigeria in 2011.

Growth Enhancement Support Scheme (GESS) represents a policy and pragmatic shift within the existing Fertilizer Market Stabilization Programme. It puts the resource constrained farmer at its center through the provision of series of incentives to encourage the critical actors in the fertilizer value chain to work together to improve productivity, household food security and income of the farmers (Federal Input Support Service, 2011). Under this scheme, fertilizer was made available through e-wallet to registered farmers and fertilizer were distributed through organized agro-dealers. The scheme claimed that 5 million farmers have been reached through their mobile phone which was a component of the scheme in 2013 and 2014. Lack of continuity of government Policy has stalled the progress made hence the scheme has not function well since 2015. Only about 15-20 per cent of fertilizer sale was attributed to government patronage when it was in operation. Farmer has resorted back to other fertilizer channels in the market. There is need to revive such scheme to improve timely availability of fertilizers to farmers at low cost. The current Agricultural Promotion Policy (2016-2020) by Nigerian government aims to build on this past approach with emphasizes on technology transfer to stakeholders.

There is need for more local production of both organic and inorganic fertilizers to attain self-sufficiency and to bring the cost of fertilizer to generally affordable price to smallholder farmers. The Farm Input Support Services Department (FISSD) was established in 1999 which has the mandate to promote research, production and adoption of organic and inorganic fertilizers has not made significant impact. Agricultural transformation needs holistic approach encompassing improved inputs and farm practices used in sustainable manner. ISFM aim is for site specific approach that does not focus on fertilizer alone but on improving fertilizer use efficiency, improved seeds and local adaptations. Hence, this could have been the reason that FISSD has not made impact, since fertilizer use alone cannot result to agronomic efficiency.

Presently, Notore Chemical Industries Plc in Onne, PortHarcourt is the only primary producer of urea, a nitrogen-based fertilizer in the country. There is need to increase more local fertilizer companies to meet the need for increased crop production. Presently, in Oyo state, the Pacesetter Organic Fertilizer launched in 1999 to convert market waste to fertilizer is not functioning well. The Gateway Fertilizer commissioned 2009 in Ogun state has been producing accelerated compost for crop production but the impact is still rather low.

Salman (2013) recommended that smaller packs of inorganic fertilizers rather than the usual 50Kg pack could also be introduced as trials in order to encourage the new farmers in SWN. There is need to educate farmers more on fertilizer use and agro dealers should be trained on the importance of effective distribution and marketing. The government should monitor and evaluate the exercise vis-à-vis quality control, periodic feedback from farmers, and put in place effective credit programs. Farmers' purchasing power should also be increased by credit facilities channeled through a well-organized and certified farmers' group and cooperative societies. Recently, farmers started organizing themselves into various commodity group to access government agricultural loan.

7. CONSTRAINTS LIMITING ADOPTION OF ISFM COMPONENTS IN SWN

Constraints limiting adoption of ISFM are many but creation of awareness through proper channels to reach all stakeholders will enhance adoption. The establishment of Nigeria Soil Health Consortium has improved knowledge of ISFM among farmers, scientists, agro- dealers and policy makers. One of the major constraints includes lack of seed of the improved crop varieties developed and released. This is caused by poor storage facility, non-availability of seed processing machine, and poor capacity of the relevant stakeholders in seed production, processing and distribution.

There is also lack of simple and low-cost input technology for organic fertilizer production. The existing technologies being evaluated in the country have not been well promoted to facilitate adoption. There is need to address lack of encouragement to farmers and commercial organic fertilizer users through provision of credit, loan or subsidies. Generally, there is poor perception and awareness of organic fertilizers in south west Nigeria. Lack of guidelines, standards, and certification scheme on agricultural wastes recycling remain obstacles to farm wastes

recycling in the country. Organic fertilizer production is highly laborious for farmers, and the fact that high quantities of materials are needed for the production has hindered good uptake. Scarcity and high cost of chemical fertilizers within the south western Nigeria has also limited fertilizer use in the zone.

Furthermore, there is also indiscriminate fertilizer application due to lack of information on soil type and characteristics. Moreover, there are only few appropriate fertilizers like SSP available for crop production. Farmers are yet to take advantages of biofertilizers due to complexity of the methods of biofertilizer production which is beyond farmers' perception. There is need for finished products (biofertilizer) to get to farmers which can be added to organic materials directly without rigour involved in extracting appropriate microorganism.

Unstable government policy on Agriculture of successive government truncates existing programs no matter how laudable the programmes are. This has led to project abandonment, policy inconsistency and waste of funds. There is also poor funding of agricultural research by government and relevant stakeholders in agricultural enterprise.

Most times research findings do not get to end users due to poor extension service delivery system for reason of low extension agent- farm family ratio of 1:7000. There are also problems of poor mobility, irregular training and workshop for extension agents, poor remuneration and general low funding of extension. In addition, there is slow up-take of research findings by investors who supposed to commercialize them because of poor public-private partnership. Moreover, farmers do not grasp the technicalities of some of the technologies. For example, perception of farmers about alley cropping technology being invasive has made it unpopular among small holder farmers. Generally, there are lots of on-shelf technologies that can solve many of the production problems, enhance productivity and sustain soil quality. Dissemination of these technologies is however poor because of the extension arm of the government lack resources to scale out the technologies.

8. KNOWLEDGE GAPS

There is dearth of scientific information on ISFM for the optimisation of yield for a large number of crops, except maize which has been research focus for a long period (Figure 5). The gradual increase in complexity of knowledge as one moves towards complete ISFM has implications for the strategies for delivery and dissemination of ISFM at a large scale. The major gap is dissemination strategies of ISFM technology to stakeholders. Dissemination of technologies should include proper demonstration plots, field days and various group discussion and farmers forum. Farmers need to be empowered through farmers' organizations and networks which can contribute to the planning and implementation of improved practices, and should be fully involved in bidding for funds and in managing them towards more beneficial land management. There is need to promote improve planting materials and appropriate fertilizer use strategies through regular training of stakeholders in seed production of important crops and fertilizer use that have direct bearing to ISFM programmes.

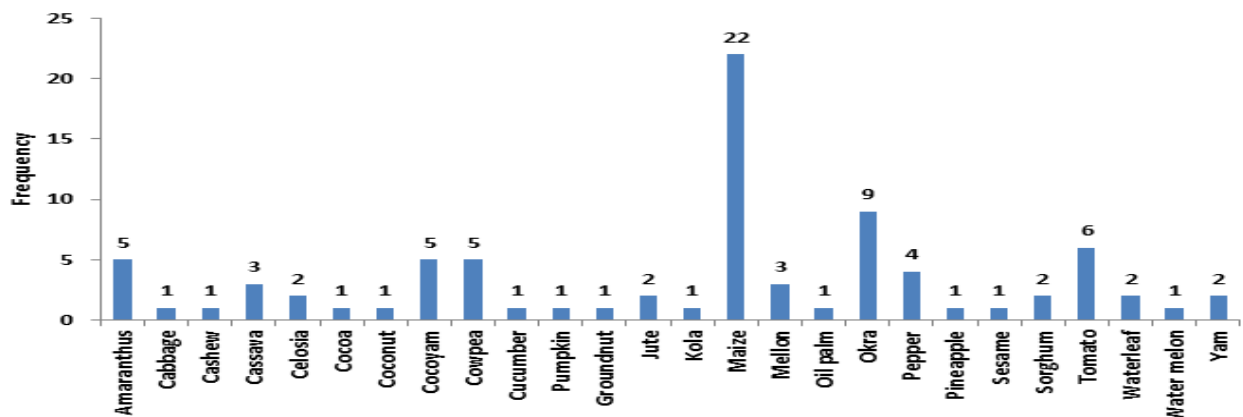


Figure-5. Frequency of crops used in ISFM experiments between 1995 and 2014

(Source: Nigeria Soil Health Consortium (South) database on ISFM protocols)

There is need for adequate funding of extension arm of agriculture in Nigeria, and privatization of this arm to allow active participation of the private sector. Possibility of private organization to take up technologies to farmers will definitely enhance rate of adoption.

Provision of adequate budgetary allocations for Agriculture by government is essential for production of seed of the improved crop varieties developed and released. Fund for good storage facility, seed processing machine, capacity building of the relevant stakeholders in seed production, fertilizer use, soil testing and research for more improved germplasm.

The Nigeria Soil Health Consortium has advocated for use of farmers as agro-dealers to militate against adulterated seeds and fertilizers being sold to farmers. This will also enhance timely delivery of inputs.

9. CONCLUSION

The use of organic and inorganic fertilizers in an integrated programme coupled with sustainable local adaptation will suffice to solve the problems of low nutrient level of soils in SWN. This approach will boost crop yield and improve continually the physical and chemical status of the referred soil types. Sustainable crop production on these soils must strongly emphasize inorganic and organic recycling using soil fertility management that enables the soil microbes to act optimally for continuous cycling of soil nutrient to maintain soil food web. ISFM approach is necessary to help farmers improve their livelihood by increasing the quantity and quality of food hence, enhancing the income of smallholder farmers. The choice of nutrient management strategies must include ecologically suitable crops, appropriate cropping systems and available resources at the farm. The knowledge of ISFM need to be urgently promoted effectively through demonstration plots, farmers field days and production of knowledge products to enhance soil quality and crop production in SWN.

Funding: This study received no specific financial support.

Competing Interests: The authors declare that they have no competing interests.

Contributors/Acknowledgement: We want to appreciate all members of Nigeria Soil Health Consortium (South) and AGRA for their contributions.

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