

Technology development of soil fertility management based on understanding local agricultural systems of the Sahel in Niger, West Africa

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Abstract

Local farmers in the Sahel have few choices for arresting soil fertility degradation due to subsistence livelihood for agriculture. However, there are some locally available materials which are not utilized for agricultural production. Through field survey on understanding local agricultural system, underutilized organic resources were identified and crops stumps and millet husk were tested for technology development. According to the obtained results through on-station experiment, crops stumps of millet-hibiscus intercropping system showed an increase of 10 kg/ha of total nitrogen in soil with a height of stumps about 10-20 cm above ground. This implies that negative nutrient balance in extensively managed farmlands can be mitigated from -9 kg-N/ha to -4 kg-N/ha. Results from on-farm trial showed better economic evaluation in developed technology than conventional practice and 95 % of participants of local farmers showed their satisfaction with the results of the technology. Through modifying conventional system based on understanding local situation, changes shown through developed technology were tangible to local farmers and consequently positive evaluation was obtained from participants.

Key Words

Millet-hibiscus intercropping system, nutrient flow, small scale farmers, wind erosion, Niger.

Introduction

The low level, irregular pattern and fluctuation of inter-annual rainfall as well as low soil fertility and subsistence livelihood are some of the identified causes of the problem that have beset agricultural productivity in the Sahel. Since they are all interconnected, identifying what the real cause could be quite complicated. Suffice it to say, the soil in the Sahel is not fertile enough. Fertility improvement for sustainable agricultural production is therefore, one of the local livelihood's utmost priorities.

Many authors have mentioned the importance of the application of inorganic fertilizer with organic amendment (Bationo *et al.* 1993). However, due to the low amount of fertilizer utilization in Africa, fertility improvement did not seem feasible. Fertilizer in Africa is expensive due to the high importation cost. The inability to allocate cash to purchase fertilizer at the start of the cropping season as well as the shortage of food at local household during this period put too much burden on the part of the local farmers (Hayashi *et al.* 2008). As enhancing the utilization of inorganic fertilizer in Africa is a time-consuming process, an effective market orientation and policy making is necessary to enable the farmer to use inorganic fertilizer more frequently compared to the present time. In the meantime, it is necessary to have a best alternative measure that will enable farmers to manage their life while waiting for higher level components to come up and implement an effective working policy.

Since organic matter is a locally available input for agriculture, many studies for its judicious use have already been carried out (Schlecht *et al.* 2004). In Africa, crops residue and animal excrements are among the major sources of locally available organic matter which the farmers use not only in agriculture but also in construction and trade. Despite such extensive use, there are still few studies about its potential for technology development in Africa.

The objective of this study is to be able to develop an appropriate technology suitable in Africa by evaluating the potential of organic resources and nutrient flow based mainly on understanding the existing local agricultural systems.

Methods

To understand the actual situation of the study site, a field survey was conducted in the three villages of the Fakara region, Dantiadou district of Tillaberi prefecture, Western Niger (Figure 1). The result of the

questionnaire survey provided us a thorough understanding of the actual agricultural system of the local farmers and at the same time enabled us to identify the specific problematic points in agricultural production. One of the identified methods to come up with a potential technology to be developed is on-station field experiment conducted at the research station in ICRISAT-Niger. Millet-hibiscus intercropping system with the use of crop stumps after harvest was considered an identified technology against wind erosion and towards suitable fertility management. Measuring several variables such as productivity, soil fertility improvement, and best conditions were conducted to identify and verify possible functions of this technology for actual practice at farmers' level. For evaluation and validation of this technology, on-farm field trial participated by the local farmers was conducted in Ko-Dey village of Fakara region. To assess the impact of the developed technology, nutrient flow through estimation of the potential of organic resources in the study site was evaluated. Field measurements and local farmers' questionnaire survey were done to obtain necessary information for this purpose.

Results and discussion

Actual situation of agricultural production system in the study area

According to the results of the field survey, local farmers own three to five areas of farmlands for agricultural production. Adjacent farmlands (AF) which received household waste, human excreta and other domestic waste were distributed around the village. Farmlands for threshing (TF) where female farmers used it for threshing crops and abundant crops husk were distributed round 100 m to 500 m from the village. Farmlands for dumping transported farmyard manure (TMF) where local farmers transported during dry season were distributed around 500 m to 1,000 m from the village. Farmlands for corralling (CRL) where Fulani, a nomadic tribe who was engaged in livestock production stayed for incorporating livestock excreta during dry season were distributed around 1,000 m to 2,000 m from the village. Extensively managed farmlands (EMF) were distributed more than 2,000 m from the village. The areas for EMF comprise the largest, occupying 66 % of the total. EMF are managed through rotation of fallow and cultivation and the period of fallow gets shorter compared to the conventional practice. Without the use of inputs, a 3 year fallow after a 6 year cultivation period was the usual management practice. Results prior to this study revealed that soil fertility in the 2 years of fallow was obviously low compared to the 10 years of fallow. This means that restoration of soil fertility was difficult to attain with just a few year period practice. Mix cropping of millet with cowpea and/or hibiscus was a common practice and combination varied depending on the type of management of the farmlands. For TF and TFM, millet is combined with cowpea. With CRL, millet was mixed with cowpea and hibiscus while for EMF, millet is mixed with hibiscus. But for AF, mono cropping of millet is practiced due to wrecks by domestic fowls and insanitary by human excrement.

Technology development based on the actual situation

As crop residue derived from millet is one of the important materials for domestic and commercial purposes, local farmers collect most of it from their farmlands after the harvest. Thus the surface of the land becomes susceptible to wind erosion during the dry season, a situation which should be taken into consideration in order to arrest soil fertility degradation.

Based on the field survey, soil fertility degradation in EMF was identified in their most critical level followed by millet-hibiscus mix cropping system, the main system practiced in this area. Due to inappropriate management practice, farmlands were susceptible to wind erosion during the dry season. Therefore, research focus was put on this system to develop a technology to arrest wind erosion. For soil fertility management purpose, crop stumps of local cropping system was utilized in the technology. Results of on-station experiment indicated significant increase in the surface level of experimental plots during the dry season. With crop stumps, the surface level rose starting at 45 days after first measurement (DAFM) while almost no change was observed on the surface without crops stumps. At 145 DAFM, the mean surface level with crops' stumps rose up to 2.25 cm. Total nitrogen content (T-N) of surface soils was 10 kg/ha higher in the surface with crops' stumps than without crops' stumps and the difference was significant by t-test ($p = 0.039$). These results were also confirmed with the second-year experiment. Crops stumps cut at ground level (as farmers' practice) remained the same as bare spots at the end of monitoring period. Stumps of millet and hibiscus cut at 10 cm and 20 cm above ground made the surface higher than that of millet mono cropping cut at both heights. The mean surface level significantly increased in millet and hibiscus intercropping than millet mono cropping with stumps cut at both ground level and at 20 cm heights. No significant difference was observed between the 10 cm and 20 cm height in millet and hibiscus intercropping.

Millet stems have high commercial value for different demands, one of which is construction materials for fence. The study of Baidu-Forson (1995) showed that barely a small quantity of crop residue remained in the field before cropping season which indicates that local farmers tried to obtain much benefit out of their production. Our results showed that the effect of crops' stumps was not significantly different for either 10 cm or 20 cm heights. This result can serve two purposes of local farmers' demand in their agricultural fields; one is to keep the commercial value of crop stems and another to increase prevention mechanisms against wind erosion for better soil fertility management.

Verification of developed technology

In order to verify the feasibility of the developed technology in the study area, on-farm field experiment was conducted with local farmers' participation and impact assessment was carried out through evaluation of nutrient flow.

On farm field trial was carried out with the active participation of local farmers. Millet-hibiscus intercropping system was designed with two different practices, application of organic amendment and timing of weeding. These are the factors which play important roles in production as the previous study showed (Hayashi *et al.* 2009). Result of crop yield showed that the millet yield of developed technology was lower than that of local farmers' practice because of the effect of intercropping (Table 1). Application of millet residue improved the yield compared to the yield without millet residue. However, the yield was reduced with the delay of weeding despite the application of millet residue. Nevertheless, the developed technology obtained the desired grain yield with the production of hibiscus and its by-product which has high value in the local market. According to the result of the questionnaire obtained, 20 out of 21 or 95 % of participants were satisfied with the performance of the technology and most of them showed their satisfaction with the better yield obtained from the production of hibiscus than the low plant density of the conventional system. The economic aspect of the technology was also evaluated using the benefit-cost ratio (BCR). Results showed that the BCR of the conventional practice was 3.9 while developed technology showed a BCR of 4.7. BCR improved with the application of millet residue despite the delay in weeding. BCR became lower than the conventional practice when no millet residue was applied and weeding was delayed.

Impact assessment through nutrient flow between village and farmlands

Millet production of farmlands in each type of management was estimated based on the quantitative measurements of the crops' yield. Results revealed that most of the production was provided by EMF. This area was also considered important because of the production of wild plants for domestic purposes, i.e. substitute of food, commercial use, livestock feed and livestock grazing. Despite the large quantity of production output from this area, most of the nutrient especially nitrogen was returned to AF and TFM. EMF did not receive any nutrient inputs except the one from harmattan dust brought by the seasonal wind from the Sahara desert during the dry season. According to the estimation, output from EMF was 86 t/year (58 t/year from crops production, 12 t/year from wild plants and 16 t/year from grazing) while input through harmattan dust to this farmlands was 21 t/year (Table 2). The previous results of the on-station experiment showed that the developed technology was able to increase 10 kg/ha of total nitrogen in soil. Thus, a 35 t/year increase in nitrogen as additional input can be estimated when the developed technology is applied to this area. This augmentation of nitrogen implies that the negative nutrient balance in EMF can be modified from -9 kg-N/ha to -4 kg-N/ha. Furthermore, land degradation through inappropriate management shall be mitigated with the developed technology and sustainability of local agricultural production can be enhanced.

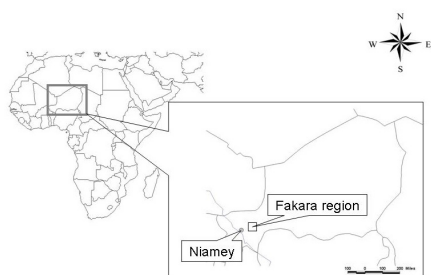


Figure 1. Study site of on-station experiment (Niamey) and on-farm trial (Fakara region)

Table 1. Yield of millet (*Pennisetum glaucum* L.) and hibiscus (*Hibiscus sabdarifa*) through on-farm trial and economic evaluation through BCR.

	Yield (kg ha ⁻¹)		BCR
	Millet	Hibiscus	
Control	164.7	n.a.	3.9
RM+SAT	101.9	410.4	5.3
RM+ST	78.4	348.3	4.4
RM-SAT	85.4	300.6	4.7
RM-ST	62.4	264.6	3.7
<i>P</i>	0.01	0.20	

RM: Residue of millet husk, SAT: weeding without delay, ST: BCR: Benefit-cost ratio

Table 2. Nitrogen balance and nitrogen use efficiency for different type of management of farmlands

Type of management	Total area	Input	Output	N balance	Efficiency
	ha	t ha ⁻¹	t ha ⁻¹	kgN ha ⁻¹	%
Adjacent farmlands	53	14.0	1.3	240.6	9.5
Farmlands for threshing	158	6.2	3.8	15.3	60.9
Farmlands for TFM	607	15.2	11.9	5.4	78.3
Farmlands for corralling	2300	22.6	19.0	1.6	84.1
Extensively managed farmlands	7080	21.2	85.6	-9.1	403.0

Conclusion

Local farmers in the Sahel have few choices for arresting soil fertility degradation due to subsistent livelihood for agriculture. However, there are some locally available materials which are not utilized for agricultural production. Through the study, crops stumps were tested in the purpose of prevention of wind erosion and results were shown to be relevant in terms of actual situation of Sahelian agriculture. According to the obtained results through on station experiment and on farm trial, the technology developed through the study showed high potential for extensively managed farmlands and inappropriate nutrient flow could be modified through restoring nitrogen content of the soil in extensively managed farmlands. Through modifying conventional system based on understanding local situation, differences between conventional and developed technology were tangible to local farmers and consequently positive evaluation was obtained from participated farmers.

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