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YIELD GAP ANALYSIS IN RICE PRODUCTION FROM STAKEHOLDERS' PERSPECTIVE AT ANNUM VALLEY BOTTOM IRRIGATION PROJECT AT NOBEWAM IN GHANA

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ABSTRACT

Rice is a major food crop in Ghana. Local production falls below demand and invariably large quantities are imported to meet consumption. Suitable rice growing ecologies exist in the Annum Valley Irrigation and also some level of inputs which includes planting varieties with high yielding potential also exist. The Nobewam project average yield was 3.87 t/ha and that on the researchers' fields were between 4-11 t/ha with an average of 7.5 t/ha for *Sikamo.* There is a need to identify and remove constraints to improving/increasing yield for each production ecology. A survey was conducted based on FAO yield gap determinants (technical, biophysical, socio-economic and policy) to identify constraints to yield from the perspective of major stakeholders (farmers, researchers and project management). Results show that the dominant constraints to yield are poor access to credit, low market price, inadequate market access, low know-how in cropping techniques and poor extension and research support which are all policy related. Others are poor water application, high incidence of pest, low soil fertility, unreliable water supply for all year round farming, untimely availability of inputs and services, inadequate machinery for land preparation and low seed quality. Proper policy initiative could set in motion actions by farmers to eliminate most of the constraints with support from research, extension and management. Policy direction could create suitable collaboration between farmers, research and extension.

Keywords: rice production, yield gap analysis, constraints, determinants, yield potential.

INTRODUCTION

Available data from the Ministry of Food and Agriculture (MoFA) reveal that whilst the estimated national rice consumption stands at 561,400 metric tons per year, rice produced locally is 107,900 metric tons per year leaving a gap of 453,500 metric tons per year, which has to be imported (Public Agenda, 2009). With a population growth rate of 2.5% and an annual rice demand growth rate of 8.9%, a supply of 1.6 million tons of rice will be needed annually in Ghana by 2015. The situation is therefore alarming as the dependency on imports will increase. There exists suitable rice production ecologies in Ghana and local capacity to produce rice can be enhanced in order to decrease the dependency on imports. According to Chaudhary and Tran (1999) approaches to bridge the gap of projected demand to current level of production could be done through the expansion of rice cultivated area (horizontal expansion), improving yield (vertical expansion), i.e., yield gap bridging, and reducing yield losses. The increase in production could not only come from expansion of area under rice cultivation or identifying suitable rice production ecologies due to competing use of land from other sectors and environmental concerns. Possible avenues for growth in yield and production would depend to a large extent on exploring ways by which yield per land area could be increased and also removing constraints to yield for each production ecology and location by yield gap analysis. Removing constraints to yield is not synonymous with outright increase in production. It must be backed with some level of commitment in terms of adoption of improved farming methods, improved technologies, research, credit and extension support given to farmers. The extent to which any of these commitments contribute to low yields will vary from one production ecology to another, hence the need to carry out a survey to identify the constraints associated with each production site. In Ghana, irrigated rice yields are known to vary from 3.5 t/ha to 7 t/ha with an average yield of 4.6 t/ha on formal irrigation schemes (FAO, 2005). Ghana Irrigation Development Authority (GIDA) has targeted an average yield of 7.2 t/ha (JICA, 2007) for *Sikamo* on its projects sites.

Rice yield potential, environment and management

Yield (genetic) potential of a cultivar can be fully expressed by the relationship such as

$$Yield\ potential = f\left(environment\ ,\ management\right)$$

The genetic potential of a cultivar depends on the existence of a favourable environment which will enable the cultivar to express its full potential in terms of the desired product (De Datta, 1981). The desired product, in the case of rice is the grain. The environment comprises soil type, weather, nutrient, disease and pests and any other factor that may prevent or enhance the expression of genetic yield potential during the season.

Favourable environment permits effective use of inputs for yield improvement. Suitable management practices involve putting in place proper agronomic practices to manipulate the environmental factors to obtain improved yield. Proper agronomic practices include correct and timely application of fertilizer, insect and weed control methods. Others are correct seedling transplanting age, varietal selection, suitable plant spacing, land preparation methods and timely application of adequate water.

Table-1. Rice yield under different production ecologies in Ghana.

Production ecology	**Yield** (t/ha)
Sawa technology +	5.0
Lowland rainfed *	2.5
Upland rainfed *	1.0
Irrigated rice *	4.6

*MoFA (2007); + Crops Research Institute (CSIR) 2007

From Table-1, there is a wide gap in yield that can be exploited to improve production instead of having to expand area under cultivation. Factors that contribute to low yield need to be identified through a survey carried out in each production ecology. According to FAO (2004) most rice varieties are not achieving their potential yields and in many countries, actual yields are about 4 to 6 t/ha, compared with a potential of 10 to 11 t/ha. The first step in narrowing the yield gap is therefore to identify and analyze actual and potential constraints to rice production in a particular area (Van Tran, 2006). Yield gap analysis is a yield diagnostic check which offers several advantages. It offers an opportunity to overhaul the whole production practices at a particular location, increase production with the additional incentives of cost reduction, poverty alleviation, and social justice and equity, improve efficiency of land and labour use, reduce cost of production, attain improved production target goal, identify the target group to change, improved efficiency of resource (land, water, labour and inputs) use (FAO, 2004, Lobell *et al*, 2009, Chaudhary, 2000, de Bie, 2002, Nirmala *et al*, 2009).

Yield gap in rice production

The factors causing yield gaps can be classified according to their nature and the degree to which they contribute to the gaps. FAO (2000) expert consultation on rice yield gap identifies four important causes of yield gaps - These are; biophysical, technical/management, socio-economic, institutional/policy and technology transfer and linkages Biophysical factors are about the climate of the area, soil type, water availability, pest and diseases. Technical aspects are connected with tillage, varietal selection and seed source, resource or input (e.g. water, soil, nutrients, seed quality, pests including weeds, harvest and post-harvest) use efficiency. Socio-economic factors include farmers' socio-economic status, household income or investment, family size, farmer's traditions and knowledge. Institutional or policy issues have to do with market price for rice, credit, input supply, land tenure, access to market, research and extension support which can be influenced in one way or the other by government policy direction. How does each of these factors constrain yield at the project site? The answer is to carry out a survey of the operations at the site and to seek opinions of stakeholders namely, farmers, researchers and project management. The aim of this work was to determine the causes of yield gaps in rice yield at the site and to suggest ways by which the gap can be narrowed to improve production.

MATERIALS AND METHODS

Annum valley irrigation project has a total potential area of about 140 ha and total irrigable area of about 90 ha. The project is community-based and has the aim of assisting small scale farmers to produce rice under irrigation. The objectives of the project are to increase the income of small scale farmers, ensure food security and to alleviate rural poverty through employment generation. As at 2004, the cropped area was 40 ha with a total paddy rice production of 160 tonnes. A farmer population of about 150 in 1992 had declined to 55 farmers as at 2005, with a 300% decrease in cropped area and farmer population (Opoku-Baffour, 2007). This has left the project in a deplorable state, thus affecting the project objectives, in terms of food security, employment and livelihood sustenance.

The survey was based on the extent to which elements of rice production practices are carried out. These are land preparation (slashing, ploughing, puddling and leveling), seeds and seed source, nursery and nursery care, transplanting(plant population, number of seedlings per hill, plant spacing, age of seedlings), pests and weed control. Others are fertilizer application, harvesting, input supply and use, availability of financial and extension support and yields. Responses from farmers, researchers and project management on the diligence and extent at which these production practices are carried out or followed and their impact on yield were the subject for the survey.

Data were collected from stakeholders at the project site including, farmers, researchers and the project management. The researchers (5 respondents), from Soil Research Institute and Crops Research Institute of the Council for Scientific and Industrial Research Institute, Ghana manage a demonstration field. Forty-one (41) farmers at the project site responded to the questionnaire. The project management includes staff maintained at the project site by the Ghana Irrigation Development Authority and Executives of the Farmer Association.

RESULTS AND DISCUSSIONS

Table-2 gives the project average yield as 3.87 t/ha. Demonstration/Research fields (Crops Research Institute) obtains yield between 4-11 t/ha with an average of 7.5 t/ha for *Sikamo* (TOX 3108) (Darko, 2007).

Table-2. Average yield levels for different stakeholders.

Stakeholder	Av. yield (t/ha)	GIDA targeted yield (t/ha)	Remarks
Demonstration field yield at Nobewam	7.5	7.2	exceeded
Formal irrigation schemes	4.6	7.2	deficit
Farmer's field (attainable)	4.0	7.2	deficit
Project average yield	3.87	7.2	deficit

The fact that researchers field average yield recorded 7.5 t/ha (*Sikamo)* points to the fact that the 7.2 t/ha target of GIDA is achievable and yield improvement is attainable on the farmer's field.

Researcher perspective

According to researchers at the demonstration fields, soils tests are necessary before planting in order to have information about the initial fertility level of soils and also to develop appropriate nutrient management system for the crop. Soil must be tested for Nitrogen (N), Phosphorus (P), Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), soil pH, Electrical Conductivity (EC) and organic matter content. According to the researchers, land preparation methods should include soil puddling, leveling, construction and maintenance of bunds. Nursery care, according to the researchers should include fertilizer application, pests and disease control to ensure quality seedlings and healthy plant stands. Nurseries should not exceed more than three weeks before transplanting and also at least two times fertilizer application after transplanting. Fertilizers application is done twice with compound 15:15:15 (NPK) as basal fertilizer and Urea (Sulphate of Ammonia) use for top dressing. Drainage is carried out two times, one for improved aeration and the other to allow for harvesting.

Table-3 shows the station yield profile for individual years covering the period 1992 to 2006 and the varieties grown. The annual yield is obtained by adding yields of all farmers and finding the average to give the station mean for the year.

Table-3. Production and yield profile of Anum valley project.

Year	Rice variety grown	Area cropped (ha)	Project yield (t/ha)
1992	Grug 7	117.34	3.3
1993	Grug 7	98.68	4.0
1994	“	29.78	4.5
1995	“	34.60	4.0
1996	“	65	3.9
1997	Grug/Tox 3108	53.78	4.0
1998	Sikamo (Tox 3108)	46.58	3.8
1999	“	44.47	4.0
2000	“	65	4.0
2001	“	62	4.2
2002	“	76	4.0
2003	“	32	4.0
2004	“	40	4.0
2005	“	30	3.5
2006	“	38	3.6

Project management perspective

The Ghana Irrigation Development Authority maintains a staff at the site to perform various functions including provision of technical, management and extension services to farmers. Other functions are operation and maintenance of the irrigation systems and other structures. The management is of the view that constraints to yield are due to unreliable seed source, low yield, poor market access, low market price of produce, and low levels of fertilizer use. Others are poor access to credit, high cost of labour, poor water management, financial constraints, inadequate equipment and machinery (e.g. power tillers), high cost of fuel for pumping water, diseases and high input cost leading to high cost of production. Management also attributes low flows in river and irrigation channels and also in low water level in weir as among the main causes of low yield trends on the project.

Farmers' perspective

Rice cropping system is made up of planting improved rice varieties, use of quality seeds, producing strong and healthy seedlings, good land preparation, proper plant populations, balanced fertilizer use, rational irrigation, control of pests and diseases. The management effectiveness with which these techniques are implemented and practiced, with suitable policy support (direct or indirect) available to farmers would determine the yield.

Table-4 shows the response of farmers to the four categories of yield constraints namely, technical, biophysical, socio-economic and institutional were the focus of the survey. Highest response among the technical constraints were poor soil fertility monitoring, inadequate land preparation methods, poor water supply to crops scoring 95%, followed by unreliable seed source which scored 73.1%. The biophysical constraints are poor water application which records 100%, followed by poor pest control and management which scored 92.7%. Among the socio-economic constraints, poor access to credit, poor market access, and inadequate access to training in cropping techniques followed by low market price which scored 90.2%. The institutional and policy constraints were about poorly timed access to inputs and services, poor extension and research support which recorded 100% followed by limited access and poorly timed credit 95% with inadequate machinery scoring 85.4%.

Table-4. Field response of farmers to important factors in rice production.

Item	Production constraints	Site Condition	No. of response	% of farmers
1	Technical	Uncertified seed source	30	73.1
		Poor pest control at nursery	13	31.7
		Poor watering of nursery plants	13	31.7
		Poor soil fertility monitoring	39	95.0
		Inadequate land preparation(no bunding, puddling and leveling) methods	39	95.0
		Poor water distribution and management	21	51.0
		Limited number of drainage times	41	100.0
		Knowledge base in fertilizer application	33	80.49
		Unreliable water supply in the dry season	39	95.0
2	Biophysical	Poor water application	41	100.0
		High incidence of pests	41	100.0
		Poor pest control and management	38	92.7
3	Socio-economic	Poor market access	41	100.0
		Low market price	37	90.2
		Poor access to credit	41	100.0
		Inadequate access to training in cropping techniques	41	100.0
4	Institutional/policy	Limited and poorly timed access to credit	39	95.0
		Inadequate machinery for land preparation	35	85.4
		Poorly timed access to inputs and services	41	100.0
		Poor extension and research support	41	100.0
		High cost of fuel for pumping	38	92.7

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Seed source

Source of seed was not credible as farmers obtained planting materials (seeds) from their friends. Out of a total of 41 farmers, 30 of them obtain their seed source from friends. This is not a good practice in terms of seed quality. According to (Ching, 2007) seed saving is undesirable when growing hybrid seeds as the first generation seeds of hybrid plants does not reliably produce true copies. Therefore, new seeds must be purchased for each planting season. Not until farmers have gained sufficient capacity in seed production and storage, that aspect should not be left in their hands. Quality seed was important factor in increased rice production. Cultivating the same variety over a period of time can lead to yield and productivity declines as varieties may develop low resistance to pests and diseases. This highlights the importance of breeding for continuous resistance to pests and diseases.

Nursery care

Farmers at the project site were asked about the nursery care practices. Mention was made about watering, pests control, weed control, and fertilizing as the practices as these ensure quality nursery which promotes healthy plants and healthy growth. Out of forty (41) respondents twenty eight (28) of them practiced pest control at the nursery and twenty-nine (29) also water the nursery plants. Proper nursery care is to produce healthy seedlings because healthy seedlings produce good crop and high yield potential. Attention should be paid to growth disorders at nursery and immediate corrective measures taken before transplanting. Growth disorders may be the result from nutritional disorders, water stress and incidence of pests and diseases.

Water management

The project has been designed for rotational distribution of water to laterals according to laid down schedules planned by management and farmers at the beginning of each season. Financial constraints and inadequate machinery and equipment for land preparation make it difficult for all farmers to start cultivation at the same time. At the time one farmer is transplanting, another farmer may just be starting with land preparation. Hence water needs of individual farmers are different. Part of the project is served by five pumps, each pump mandated to serve a specified number of plots. Farmers in one of the blocks have to bear the cost of water supply to their plots themselves in addition to the irrigation service charge. Water supply and availability at the site depends on three factors namely, the season, cost of pumping and asymmetry in field water demand. During the rainy season the supply can either come from the weir or direct pumping from the river to the fields. In the dry season water level in the river, weir and ditches are so low that there is hardly any flow or pumping. Farmers cannot take advantage of the year round availability of water to increase production. Farmers may not apply the right amount of water needed by the crops because the additional financial burden of the cost of pumping. Farmers are dissatisfied with water supply and distribution system. About 33 out of 41 of the farmers who responded to the questionnaire drain their fields once when they are about to harvest the crop. For good management practice, field must be drained more than once to improve aeration and reduce soil iron toxicity.

Pests and disease control

Pests control is not planned but is based on as and when it occurs (adhoc management) and 37 out of 41 farmers who responded to the questionnaire said they would apply control measures when outbreak occurs. Farmers don’t have the capacity for early detection of the disease and that may affect yield. By the time they are able to detect the disease it might have caused much damage to their crops. Only 4 out of the 41 carry out preventive management measures. About seventeen (17) of the farmers apply disease control measures three weeks after transplanting and nineteen (19) more than three weeks after transplanting. Major pests are stem borers, cutworm, army worm and plant bug, with stem borers having the highest incidence. For diseases, the most common ones are the seedling blight. Farmers need training in integrated pest management techniques.

Soil fertility management

Nutrients in the form of fertilizer must be applied to supply the additional need of the rice plant which cannot be supplied by the soil. According to (FAO, 2000), nutrient uptake is affected by several factors, including climate, soil properties, amount and type of fertilizer applied, cultivar and method of cultivation. Pre-cultivation soil fertility check was very necessary to be sure of the fertility status of the soil before cultivation. Thirty-four (34) of the farmers keep permanent plots. Thirty-nine (39) of the farmers do not do any soil fertility check before cultivation. Plant nutrient requirements can be categorized into major and minor elements. Each one of them plays important roles n the growth, development and yield of rice plant. According to Tiwari (2002) rice productivity can be sustained by planned applications of nutrients that the soil cannot provide and that omission of nutrient, micro or macro, leads to progressive deficiency as a result of crop removal. Thirty nine (39) of the respondents apply NPK (5 bags/ha) and Urea (2.5 bags/ha). Thirty-three (33) of the respondents apply fertilizers three times after transplanting which is different from what is done on the researchers’ fields. Does that mean farmers over apply the fertilizers or that farmers are technically incompetent? If that is in excess of the required amount what will be the long term effects of the over application on soil health and crop yield? Farmers typically lack knowledge on the most effective use of fertilizer on their fields. Farmers need adequate amount of fertilizer at the right time to obtain high yields in rice cultivation. The ineffective use of chemicals makes the rice plant prone to diseases, damage to the environment, and low profits (Datta, 1981). The need to develop and disseminate improved integrated nutrient in order to increase the profitability of rice farming is paramount.

Field operations, cultural practices and timing

Farmers first slash the field after which power tillers are used to prepare the fields. Due to inadequate number of power tillers to serve all the farmers, land preparation is poorly timed and this affects uniformity of the operation among farmers. After rotor tilling, bund repairs, puddling and leveling follow. Land Leveling, puddling and bunding affect soil plant water relations as well as plant growth and yield. Land leveling ensures uniform application of water and that also promotes uniform growth of plants. It allows for maintenance of a uniform water depth and greatly facilitates uniform crop stand establishment, weed control and field drainage. Soil puddling reduces soil moisture loss due to percolation and that also ensures soil moisture availability to plants and results in water conservation. Bunding confines water to the basins and reduce runoff and should be done before the season starts.

Rice, like other annual crops has distinct phases of development and each phase has specific growth and nutritional requirements. Failure of operations at one stage may not be adequately compensated for by corrective measures or practices at a later stage. Correct timing of production practices such as land preparation, transplanting, fertilizer application, water application, pests and disease control is needed for best yield. Proper integration of land preparation, transplanting, fertilizer application, water application, pests and disease control is needed for increased yield.

According to the survey, not enough power tillers are available to farmers. Not all farmers can be served at a time resulting in delays in land preparation, culminating in delays in planting and non-uniformity in water application scheduling. The non uniformity creates water management problems because for a particular irrigation block there will be some crops at different growth stages leading to different crop water requirements, meanwhile water has to be applied from the same source.

Financial constraints

Cost of production is estimated based on the production elements listed in Table-5. Limited and untimely availability of credits to the farmer affect timely delivery, availability of essential services and application of inputs. Credit for maintenance of bunds, desilting of ditches, pump maintenance and servicing, purchase of inputs (e.g. fertilizers, weedicides, insecticides, and fungicides), payment for machinery services and water supply should be made available well before the season starts. Access to market and good price for produce was a concern among the farmers. According to 2006 estimates, production cost was GH¢897.5/ha. One 50 kg bag of paddy rice was sold for GH¢30 and an average yield of thirty three bags (33) would give GH¢990. Excess income over expenditure per hectare was GH¢92.5/ha. Additional cost of GH¢13.7 is incurred on water supply for farmers who operate in Area A. The end result is poor recovery of loans as farmers cannot break even due to poor market for what they produce.

Table-5. Elements that go into production cost of rice.

Inputs	**Machinery**	**Labour** (hired)	**Irrigation service**
Seed	Power tillers	Slashing	Water charges
Fertilizer (NPK, Urea)	Threshers	Transplanting	Cost of pumping
Chemicals for pests , weed and disease control	Winnower	Bund maintenance	Canal maintenance
	Milling	Bird scaring	Carting
		Harvesting	Infrastructure service charge (ISC)
		Carting	
		Hand weeding	

Policy, research and extension support

According to Issaka *et al* (2007) policies have significantly influenced rice production in Ghana. Favourable policies on subsidies for both fertilizer and machinery brought about large scale rice production in 1960-1970 and the country achieved self-sufficiency in rice in 1974-1975. Policy support should examine all the aspects of production as listed in Table-5 and determine where subsidies can be applied to support the needs of farmers.

A more responsive and well-resourced extension service should work hand-in-hand with researchers and farmers to better understand farmers constraints to high rice yield and provide farmers with appropriate technological packages at specific locations to bridge the gaps under participatory approaches. The extension service should ensure that farmers use correctly and systematically recommended inputs and production methods through effective training and demonstrations.

A research wing should be established specifically as a component of the project to take care of farmers' training, technical and other production needs. Researchers must work closely with farmers to develop farmer-based technologies that are easily acceptable to farmers and will help remove constraints to yield. The effectiveness of suitable linkages and support to farmers is as illustrated in Figure-1. A well supported and funded research wing should be a major component of any rice growing enterprise to identify farmers' problems and address them. There is therefore the need for more government resources and commitment in terms of policy to set in motion needed actions to support farmers. Government support for research should be directed at providing the facilities, resources and staff capacity, researching into problems that may affect the crops over short term and long term. These include crop response to fertilizer, soil management, water application methods, integrated pests and disease control and developing disease resistant rice varieties.

Policy support for acquisition of equipment for land preparation, credit for the purchase of inputs, timely availability of service and inputs, price, marketing, extension and research support must be encouraged. Farmers' capacity and willingness to adopt new and improved technologies, best management production practices depend on their financial strengths.

Production methods on farmers fields are different from what pertains on the researcher fields, hence the difference in yields. Researchers are aware of the importance of correct timing of land preparation, transplanting, soil fertility monitoring, need to maintain farm bunds, land leveling, puddling, correct fertilizer application, proper nursery care and field aeration. Farmers can take care of their needs if well-resourced and supported. Policy initiative that increases their access to market and ensure competitive price for what they produce will increase their capacity to pay for the needed inputs and services. They can pay for loans and increase their creditworthiness, pay for training, research and extension services that may be available to them.

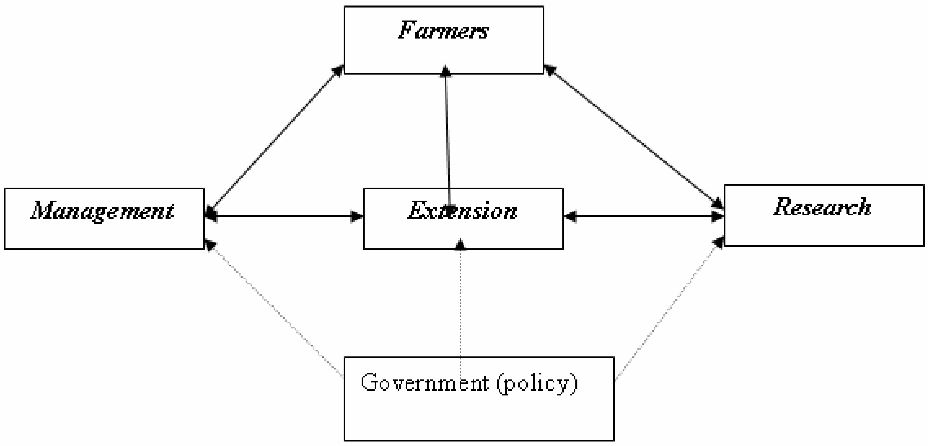

Figure-1. Framework for support services to the farmer.

CONCLUSIONS

At the project site and under farmer's conditions, yield gaps are high (47%) owing to poor access to credit, services, and inadequate water availability especially in the dry season due to low flows in the rivers and in weirs. Other yield constraints are poor market access, low price, inadequate training, poor research and extension support to farmers (which borders on policy support from the government), untimely or poor land preparation and other farm operations in general. Timely land preparation is possible when there are enough power tillers to serve all farmers during the season. Policy support can be directed at providing machinery services to farmers or having machinery sold to farmers on credit. Timely transplanting, healthy nursery care, water application, pests and disease control, plant protection and harvesting will improve yield. Wrong timing of farm operations could result from poor access to credit as farmers need credit to pay for inputs and services. Correct and timely application of fertilizer for proper growth and development at all growth stages are essential in contributing to yield increase. Yield gap analysis offers opportunity to improve production, improve infrastructure and policy requirements that will create jobs, increase productive capacity of the people and the agricultural industry. Having exhausted the yield gaps would mean fully exhausting opportunity to improve production, fully provide all the infrastructure needs, improved capacity building for research, extension and farmers. The yield gap analysis for the project clearly shows their shortfalls and the corrective measures necessary to improve production at Nobewam. Improvement in yield will increase profitability and renewed interest in rice cultivation.

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