Acta Scientific Agriculture (ISSN: 2581-365X)

Volume 3 Issue 2 February 2019

Research Article

Rice Strategy for Nepal

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Received: December 18, 2018; **Published:** January 30, 2019

Abstract

Rice is the principal food grain crop in Nepal followed by maize and wheat. The total area of Nepal is approximately 1.5 million ha with the average productivity of 3.2 t/ha producing 4.8 million tons of paddy rice. Nepal Agricultural Research Council (NARC) is the sole public organization in Nepal that conducts rice research in the country. Rice research in NARC is coordinated and implemented by National Rice Research Program (NRRP), Hardinath, Dhanusha District in coordination with Regional Agricultural Research Stations (RARS) and Central Disciplinary Divisions, Kathamandu. Department of Agriculture (DoA) under the Ministry of Agricultural and Livestock Development (MoLD) is responsible to disseminate rice technologies to farmers' fields.

Presently, the investment in rice research is very low in Nepal with less than 0.1% of the value of rice output being invested in rice research. Rice research program in NARC also receives less share of the agricultural research budget (only 4% of the total research budget) despite the vital share of rice output (20%) in national Agriculture Gross Domestic Product (AGDP). In the past five decades, rice production in Nepal increased nearly 2.2 times from 2.1 million tons in 1961-63 to 4.8 million tons in 2010-15. During the same period, rice production grew at the rate of 1.8% per annum which was below the population growth rate of 2.3% per annum. As a result, the rice self sufficiency ratio declined significantly over time. In recent years, the rice self sufficiency ratio is below 100, which means domestic rice production is not sufficient to meet the domestic consumption.

Irrigated rice accounts for 56% of the total rice area in Nepal. Thus, large rice production still occurs under rainfed condition. Government of Nepal has given priority for irrigation infrastructure development for bringing more rice areas under irrigation. The major constraints to rice production and priority in rice research and development agenda in Nepal are discussed for making Nepal rice self sufficient.

Keywords: Strategy; Irrigation; Rice production; Cultivation

Introduction

Economic growth of Nepal is determined largely by the growth of its agriculture sector, which contributes one-third to the Gross Domestic Product (GDP). Out of the total population 0f 26.5 million, almost 80 percent reside in rural areas and are predominantly employed in agriculture. The Gross National Income per capita is only US$742 [1] and growing at a slow rate. The per capita income of Nepal is lowest among the South Asian countries. The poverty ratio, defined as the proportion of the people with incomes less than Purchasing Power Parity (PPP) $1.25-a-day, is estimated to be 25%. Nepal has made significant progress in poverty reduction in the last two decades, yet poverty is still widespread. Poverty is largely a rural and agricultural phenomenon. About 16% of the population is undernourished [2]. Given the importance of the agricultural sector in Nepal, the overall economic growth and food security in the country largely depends on the performance of this sector.

Major Constraints to Rice Production in Nepal (Problem)

The research dialogue between NARC and International Rice Research Institute (IRRI) few years back identified the following major constraints to rice production in Nepal and have been collaborating to work on:

- Land constraints
- Large yield gaps
- Inappropriate technologies especially in rainfed areas

- o Problems of product quality and timely delivery of inputs
- o Limited access to new technology and inefficient technol ogy transfer
- o Inadequate policy support

While most lands in Terai are suitable for rice cultivation, only a small fraction of land in the hills and mountains are suitable for rice cultivation. The growing rural population has been reducing the per capita availability of rice lands. Average farm holding declined significantly from 0.95 ha/hh in 1991 to 0.66 ha/hh in 2011. Therefore, availability of rice lands is a critical constraint to increase rice production in Nepal.

In the early 1960s, the rice yield in Nepal was highest in South Asia. But, now the rice yield in Nepal is lowest in South Asia (Figure 1). In comparison to Bangladesh, the per hectare rice yield in Nepal is 1.4 ton lower. Crop simulation models have shown yield gaps of 50% in rice in Nepal [3]. This shows a large scope to increase rice productivity and production in Nepal.

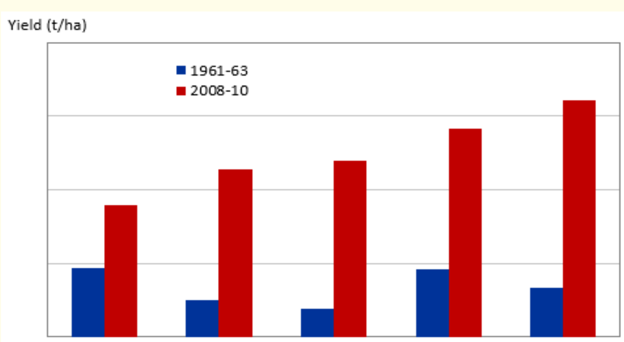

Figure 1: Average paddy rice yield in South Asian countries, 1961-63 and 2008-10.
Data source: FAO [5].

Besides sub-optimal nutrient management, the poor soil and crop management practices (e.g., use of poor land preparation, poor and untimely crop establishment, insect, disease and weed management) of farmers also contribute to poor yields [4]. In addition, abiotic stresses, particularly drought and floods, are important yield limiting factors in rainfed rice areas. These have become more prevalent in recent years due to changes in rainfall pattern. The area affected by drought is estimated at 0.52 million ha in Nepal. Rice technologies that minimize production loss from abiotic stresses are inadequate and not easily available to farmers.

In addition to several technological constraints, a number of socioeconomic and policy constraints limit the growth opportunity of the rice sector in Nepal. For example, increase in farm labor wage rates, increase in prices of material inputs and groundwater irrigation, lack of adequate irrigation facilities, and collapse of farm-gate prices in Nepal following a bumper harvest in border areas of India has lowered farmer incomes and reduced incentives to adopt yield-increasing technologies. Similarly, opening up of the world market for rice following WTO is likely to alter the comparative advantages associated with rice production in different parts of Nepal. Also despite availability of well-proven technologies of integrated crop management practices for increasing rice productivity at reduced costs, these technologies have not reached to the farmers. The main reasons are poor research-extension linkages and very inefficient extension infrastructure. There is a huge shortage of extension technicians and officers to provide services to the farmers.

Review of Literature

Rice Production Environments

Rice is grown in three different ecological environments in Nepal running parallel from east to west: from the lowland in Terai (50-300 masl) to the hills (>300-1500 masl) and mountains (>1500-3000 masl) as shown in figure 2. These ecological regions have distinct geological, soil, climatic, and hydrological characteristics, which results in distinct land use patterns. Rice is grown in all these regions covering mountain slopes, hill terraces, intermountain basins, river valleys, and Terai in flat lowland plains bordering India [6]. The Terai is referred as the "granary" of Nepal, which consists of flat and fertile alluvial land that extends from the Indo-Gangetic plains at the altitude of 60 to 800 metres of Mahabharat foot-hills. The share of rice area and production, and the level of rice yield varies by these ecological regions, with the largest production share (73%) in flat land of Terai followed by the hills (24%) and lowest in the mountain region (4%). Yield is also higher in the Terai than in the Hills and Mountains.

Figure 2: Map of Nepal showing three ecological regions.

Rice is the principal food grain crop in Nepal followed by maize and wheat. On average, Nepalese consume about 120 kg milled (or 200 kg paddy) rice per year. Rice contributes about 20% of the Agricultural GDP and one-third of the total calorie intake in Nepal. Rice alone contributes 53% to the total cereal food production. During the triennium 2010-12, the average area of 1.5 million ha and the average yield of 3.0 t/ha produced 4.5 million tons of paddy rice. The rice yield in Nepal is lowest in South Asia. In the last decade, rice production recorded highest in 2013-14 but it was lowest in 2006-07 and 2009-10 (Figure 3). As compared to the previous year, rice production declined by 13% in 2006-07 and by 11% in 2009-10 due to severe early drought and late monsoon rain.

Figure 3: Trends in area, production and yield of paddy rice, Nepal, 1990-2014.
Source: Data from MoAD [7].

Rice Research Organization and Research Investment

Presently, the Nepal Agricultural Research Council (NARC) is the sole public organization in Nepal that conducts rice research in the country. Rice research in NARC is coordinated and implemented by National Rice Research Program (NRRP), Hardinath, Dhanusha District in coordination with regional agricultural research stations (RARS) and Central Disciplinary Divisions, Kathamandu. Even though, initiation of rice research dates back to the early 1950s, a more systematic coordinated rice research program was initiated in 1972 with the establishment of the National Rice Improvement Program (NRIP) in Parwanipur, Bara District. This program was later renamed as NRRP under NARC and shifted its office from RARS Parwanipur, Bara District to Hardinath, Dhanusha District.

Presently, the investment in rice research is very low in Nepal with less than 0.1% of the value of rice output being invested in rice research. Rice research program in NARC also receives less share of the agricultural research budget (only 4% of the total research budget) despite the vital share of rice output (20%) in national AGDP [8]. Limited resources and insufficient technical capacity have constrained NARC to conduct and effectively coordinate research activities and strengthen its ties with national and international research centers.

Rice Production Scenario

In the past five decades, rice production in Nepal increased nearly 2.2 times from 2.1 million tons in 1961-63 to 4.68 million tons in 2010-12. During the same period, rice production grew at the rate of 1.8% per annum which was below the population growth rate of 2.3% per annum (Figure 4). As a result, the rice self sufficiency ratio declined significantly over time (Figure 5). In recent years, the rice self sufficiency ratio is below 100, which means domestic rice production is not sufficient to meet the domestic consumption. In other words, the country has to import rice to meet the domestic demand. While Nepal was a marginal exporter of rice before 1980, it has now turned a rice-importing country due to the combined effects of a slow growth in yield and a rapid growth of population.

Figure 4: Trends in population and rice production, Nepal, 1960-2012.
Data source: FAO [5] and MoAD [7].

Figure 5: Trends in rice self sufficiency ratio, Nepal, 1961-2010.
Data source: FAO [5].

The production condition of cereals is also almost same to that of rice. The data for 2001-2008 shows that Nepal is the only South Asian country where the growth rate of cereal production trails behind the growth rate of population (Figure 6). Consequently Nepal's domestic production has not been able to fulfill local demand and the country has been a net importer of cereals since the 1980s.

Despite slow growth in cereals output, per capita availability of cereals in Nepal is second highest in South Asia due to the food imports especially across the open border with India. Even though Nepal has a relatively high per capita cereal supply, the low income levels is a constraint for adequate food consumption by a large section of the population [9].

Figure 6: Average annual growth rates of population and cereal physical production in South Asian countries.
Source: Adopted from IFPRI [10].

Rice production increase in Nepal was due to increase in both area and yield. During 1961-2010, area increase contributed 46% to the growth while yield increase contributed 54% to the growth in rice production (Table 1). The adoption of improved modern varieties and new technologies has led to the yield increases. During the last three decades, the annual growth rate in rice yield was relatively high (3.47%) during 1981-1990 but it was very low (0.19%) during 2001-2010.While the rice area expanded substantially in the past, it has remained constant and even decreasing in recent years due to multiple reasons, such as urbanization, industrialization, and shifting from rice to non-rice crops. As the possibility for further physical expansion of rice area is limited, the only remaining option to enhance rice production is through increases in rice cropping intensity and in rice yield.

Rice	1961-70	1971-80	1981-90	1991-00	2001-10	1961-10
Area	1.04	0.86	1.45	1.73	-0.23	0.79
Yield	-0.32	-0.76	3.47	2.01	0.19	0.94
Production	0.72	0.10	4.92	3.74	-0.04	1.73

Table 1: Annual percentage growth rate in area, production, and yield of rice, by decade, Nepal, 1961-2010.
Data source: FAOSTAT (2014).

Irrigated rice accounts for 56% of the total rice area in Nepal. Thus, large rice production still occurs under rainfed condition. Out of the 44% of rainfed rice area, 39% is rainfed lowlands and 5% is rainfed upland. Even for the irrigated rice area, the supply of water is not highly reliable with the production conditions in large area resembling that of the rainfed environment. This is also reflected by a relatively low rice yields of improved varieties in irrigated rice (3.5 t/ha). Rice yield is substantially low in rainfed condition (2.45 t/ha). Rice yield is much lower for local varieties. The low rice yields in both irrigated and rainfed conditions pinpoint large scope to increase rice production and thereby improve food security in Nepal (Table 2). Under rainfed environment, rice productivity and sustainability suffer with biotic and abiotic stresses, which are compounded by climate forced changes such as extreme temperatures, severe changes in rainfall pattern resulting in drought and submergence at different crop growing stages. Adoption of modern varieties (MVs) of rice has increased significantly in Nepal. Currently, MV covers about 96% of the total rice area [7]. However, the average yield of MVs is low at 3.5 t/ha and the yield difference between the modern and traditional varieties is only 1.15 t/ha. Due to poor land, water and crop management including sub-optimal usages of nutrients, large yield gaps exist.

	Paddy irrigated		Paddy rainfed		Overall
	Improved seeds	Local seeds	Improved seeds	Local seeds	Average yield
Mountain	2.55	1.80	1.81	1.07	1.99
Hills	3.36	2.18	2.40	1.81	2.72
Terai	3.50	2.33	2.52	2.04	3.03
Nepal	3.44	2.29	2.45	1.90	2.91

Table 2: Paddy yields (t/ha) of improved and local seeds under irrigated and rainfed conditions, Nepal, 2008/09
Source: Adopted from IFPRI (2010).

Although the prevalence of undernourishment in Nepal is lowest among all South Asian countries, 16% of Nepal's population is still undernourished or unable to meet their minimum dietary requirements [10]. Also, the nutritional outcomes for children are poor in Nepal. Almost 50% of children are stunted and almost 40% of children are underweight in Nepal. Rice being the staple food and also an important source of income, increasing rice yield can help reduce undernourishment and improve nutritional outcomes for children.

Rice Demand Scenario

Based on the average per capita milled rice consumption of 122 kg per year [11] and total population of 27.6 million, the total demand for milled rice in Nepal is estimated at 3.37 million tons (5.04 million tons of paddy) in 2012. But the country produced only 2.97 million tons milled rice (4.50 million tons paddy). Assuming that only 80% of total harvest is available for human consumption, the total milled rice produced in the country available for consumption is only 2.38 million tons (3.60 million tons of paddy). This means the country has a shortfall of about 1 million tons of milled rice (1.5 million tons paddy). The future demand for rice in the country will be driven primarily by two factors: the population growth rate and the per capita income growth rate. Although the population growth rate in Nepal has declined over time, it is still high at 1.2% per annum. The per capita consumption level cannot be maintained at the current level unless the rate of growth in rice production is at least equal to the rate of population growth. However, the historical rate of growth in rice production has been only 1.76% per annum.

In addition to the population growth, income growth also creates additional demand for rice. The current demand for rice may be low due to low levels of income. As income rises, the demand for rice can be expected to increase as rice substitutes for coarse grains that are currently being consumed. In addition, as the country marches towards improved governance, economic growth, and infrastructure development, the food habit likely to change in favor of rice which would increase rice demand. Infrastructure development particularly increased road access to remote hills and mountains will increase demand for rice substantially due to availability of rice in cheaper price. For Nepal case, elasticity of demand for rice should be relatively higher than most South Asian countries because of the effect of road access in remote hills and mountains where coarse grain consuming population is significant. Current observations also show that trend of people switching from coarse grains to rice is rapidly increasing in hills and mountain areas with cheaper availability of rice from the increased road access. The income elasticity of demand for rice in Nepal is considered to be 0.3, which means one percent increase in income per capita will raise the rice demand by 0.3 percent.

Based on low and high growth per capita income growth rates (low 3% per year and high, 6% per year) as well as low and high population growth rates (low, 1.1% per year and high, 1.3% per year), the projected rice demand for Nepal up until 2035 is depicted in figure 7. Under low income growth and low population growth scenario, the paddy rice demand for 2035 is estimated at 7.97 million tons.

Assuming that only 80% of total rice produced is available for consumption, the required rice production is estimated at 9.97 million tons. This refers to the rice production increase of 120% from the current level. Under high income growth and high population growth scenario, the paddy rice demand for 2035 is estimated at 10.26 million tons. This implies the required rice production is estimated at 12.83 million tons. This refers to the rice production increase of 185% from the current level. Thus, depending upon the assumption used, rice production must increase by 120% to 185% to meet the additional demand for rice. Most of this additional supply must come from yield growth, as the possibility for expansion of physical area is limited. If we assume that one-third of the additional rice requirements is met by increasing the rice cropping intensity through expansion of irrigation facilities, rest two-thirds of the additional rice requirements must be met by increasing rice yields. The yield of rice needs to be raised from the current 3.0 t/ha to 6.0-7.0 t/ha by 2035 assuming that the current rice area will not decline and one-third of the extra rice demand is met by double rice cropping. This is a daunting challenge for rice researchers in Nepal.

Figure 7: Projected paddy rice demand in low and high income growth and population growth scenario, Nepal, 2012-2035.
Source: Authors' estimation

Methodology

Strategies for Rice Research and Development

The Agricultural Perspective Plan (APP) of Nepal, a 20-year vision document for agriculture development (1995-2015) as well as recently formulated Agricultural Development Strategy (2013), which is in the process of approval from Government of Nepal, envisions an agriculture-led economic growth strategy. Such an economic growth strategy is expected to inclusive and directly reduce poverty. Rice is the most important food crop of Nepal as it accounts for 50% of the food supply of the country and 40% of the total daily caloric uptake. Thus, food security is synonymous to rice security in Nepal. In addition, more than 80% of the population is dependent on rice farming and related enterprises for their livelihoods. On the one hand, increase in rice production and profitability is critical for poverty reduction and on the other hand, rice yield in Nepal is lowest among all countries in South Asia and the government's investment on rice research and development is very small. Clearly, there is a need for developing rice strategy to accelerate the growth rate in rice productivity of Nepal. The current level of rice yield could be substantially increased with the use of new high yielding varieties and with the integrated application of good management practices. In addition, new rice-based rotations should be developed and extended to farmers to maximize intensification, input use, increase efficiency, and reduce production costs. Conducive policy environment is similarly needed for rapid diffusion of these improved technologies. Creation of alternate rural employment opportunities in the farm and non-farm sectors is also vital to enhance farmers' income and livelihood systems and reduce poverty.

Vision

- o Alleviate poverty and ensure food and nutritional security of Nepalese rice farmers and consumers
- o Sustain natural environments in Nepal

Mission

Develop and disseminate sustainable rice production technologies to enhance rice productivity, resource use efficiency, and profitability of rice cultivation without negative effects on the environment.

Focus

To accomplish the vision and mission of the rice research and development program in Nepal, a set of priority areas have been identified. These priority areas are discussed in the subsequent section.

Priority Rice Research and Development Agenda for Nepal

The overall goal of the rice program should be to increase the national rice yield at least by 3.0% per annum for the next two and half decades through use of high yielding varieties, improved crop management practices, improving efficiency of input use, and reducing the cost of cultivation. A comprehensive rice research and development program would require concerted effort in following components.

- o Development and promotion of high yielding, stresses tolerant and better grain quality rice varieties
- o Integrated crop and resource management for sustain able rice production
- o Development and promotion of small-scale mechaniza tion and post harvest technologies
- o Socioeconomic and policy research to craft farmer-friendly policies
- o Investment in rice research and extension
- o Capacity building in strategic frontier areas of rice research

Development and promotion of high yielding, stresses tolerant and better quality rice varieties

The main reason for low rice yield in Nepal is the unavailability of high yielding varieties suitable for the local agro-ecologies. There is strong need for suitable high yielding and stresses tolerant rice varieties for irrigated and rainfed ecosystems. New advances in plant breeding have significantly reduced the breeding cycle and provided opportunities to develop new varieties in cost effective manner. Government should invest adequate resources in plant breeding to develop improved rice varieties, particularly focusing on high yielding inbreds, hybrids, and stress tolerant varieties to provide options for farmers in irrigated ecosystems and in highly diverse lowland rainfed production systems. Improved varieties should address both biotic stresses (i.e. insect and disease) as well as abiotic stresses (i.e. droughts and floods). This will require investment in fast track marker assisted breeding and biotechnological tools. This is in line with the recently approved Seed Vision (2013-2025) and Agricultural Development Strategy (2013) which emphasize on faster development and release of farmer preferred high yielding varieties to increase crop productivity and farmers' income. There is a need of increased emphasis on adaptive research and participatory plant breeding to select best varieties from the existing varieties grown by farmers and out-scale them to the suitable agro-ecologies so that rice production can be increased even with minimum investment.

Rainfed lowlands would require special attention because of its large area and thereby potential to meeting the future rice demand. Short duration rice varieties in the wet season bring opportunities to cultivate extra cash crops like mustard, thereby increasing farm incomes. These varieties should be tailor made to have opportunities to adjust cropping calendars to develop more effective and profitable cropping patterns. Together with short-duration stress-tolerant varieties, site specific crop management practices should be developed to ensure high and stable productivity in unfavorable environments.

As per capita incomes rice, consumers demand better grain quality rice and they are willing to pay higher price for better quality rice. Therefore, growing urbanization and rising per capita income will increase the demand for fine grain, aromatic, and premium quality rice. Adoption of better grain quality rice varieties is one way to increase farmers' income because premium grain quality rice varieties can fetch higher price in the market. Rice scientists should develop and promote premium quality rice varieties.

Integrated natural resource management for sustainable rice production

Rice scientists should emphasize on developing environment-friendly, site-specific crop and resource management technologies that will help farmers realize the full potential of new rice varieties. Rice yields are low and large yield gaps exist between what farmers are harvesting in their rice fields and what has been demonstrated by the research. In irrigated riceland (constituting 56% of the total rice area), rice yields are low and highly variable due to irregular and uncertain water supply to rice fields as a result of deteriorating irrigation infrastructure. The importance of irrigation, improved quality seeds, and timely availability of quality fertilizers to increase rice yield is well known. The government should provide subsidy to newly released rice varieties to replace the old rice varieties.

The Agriculture Perspective Plan stresses irrigation as one of the priority input for agriculture. Given the high investment and long lead period in large surface irrigation but rich endowment of groundwater resources, groundwater irrigation provide opportunities to develop cost-effective irrigation facilities in short time. Shallow tubewells have advantage in terms of low capital requirement, low lead time, and quick returns to investment [12]. This warrants appropriate programs and policies to boost investment for irrigation, particularly on groundwater irrigation. The effectiveness of farmers' management irrigation system is well established. Therefore, the government should help build the capacity of farmers' managed irrigation system and water users' association for effective management of existing public irrigation systems.

It is beyond doubt that water scarcity is a looming crisis in agriculture. The water scarcity problem will become more severe in the future due to growing demand for water from non-agricultural sectors and due to climate change effects. Rice farming is also under pressure to reduce water use due to its large environmental footprints. Therefore, it is important to develop and promote water saving technologies among rice farmers.

Most farmers in rainfed and irrigated areas are not using adequate inputs due to problems of product quality and timely supply of inputs. The intensity of use of improved seeds and inorganic fertilizers in cereals is very low in Nepal (IFPRI, 2010). In fact, use of improved seeds and fertilizers in cereals in Nepal is one of the lowest in the region. This has caused low yields. For instance in the Terai, improved rice seeds under irrigated condition gave more than 1.5 t/ha higher yield than local seeds under rainfed condition (Table 2). The cost of production is high, but the yields are low, resulting in very low profit to farmers. Rice scientists should focus to develop and promote efficient crop and resource management options to simultaneously increase and sustain rice productivity and profit in rainfed and irrigated rice systems.

Soil quality and soil fertility degradation is a common phenomenon in rice farming. This has compelled farmers to use more fertilizers over time even to obtain same amount of yields. There is a strong need to promote sustainable soil management technologies so that rice productivity can be increased in a sustainable way. Some options in this regard include combining use of inorganic fertilizers with organic fertilizers such as compost, vermin-compost, and green manures. Development and promotion of conservation agriculture technologies like minimum tillage also help to improve soil qualities.

Development and promotion of small-scale mechanization and post harvest technologies

Labor scarcity is an emerging constraint in Nepal. Farm wage rates increased more than four folds in the last one decade. For example, the average farm labor wage rate increased from 75 Rs/day in 2003 to 290 Rs/day in 2013. This has increased the production cost and has reduced farm profitability. As rice is most labor intensive among cereal crops, rising labor costs will reduce its comparative advantage and encourage farmers to shift from rice to non-rice crops unless labor costs are reduced. The changing demographic structures, rural outmigration, ageing of farming population, and rapid growth of the non-farm sectors is expected to further aggravate labor problems in the future. Mechanization is one option to overcome this problem. Given the small farm size, the small-scale machines and custom hiring arrangements of machine are appropriate for farmers. It is important to assess the machinery needs of farmers and promote mechanization that meets the farmers' requirements. Government need to adopt suitable policies that promote small-scale mechanization and thereby reduce the production costs.

About 15% of rice harvest is lost in post-harvest operations. The losses arise due to spillage and grain loss in all postharvest processes, losses to animals and pests, and inefficient rice milling. Therefore, reducing post-harvest losses provide good opportunity to increase rice supply in the country. Most rice farmers in Nepal use traditional technologies on threshing, transport from field to storage house, winnowing, drying, storage, and milling. In most cases, suitable technologies are not available to reduce postharvest losses. Even if such technologies exist, farmers lack the necessary knowledge, entrepreneurship skills, and resources to obtain and apply technologies to reduce losses and increase income by adding value. It is essential to develop and promote post harvest handling and agro processing technology to reduce post harvest losses. Development and promotion of postharvest technologies particularly on drying, strong, and milling will have large impacts. Therefore, rice scientists should give high priority on these technologies. Research on product diversification and value addition is another important area to increase income of rice farmers.

Socioeconomic and policy research to craft farmer-friendly policies

Socioeconomic and policy-related constraints also limit the growth opportunity of the rice sector in Nepal. For example, higher cost of production arising from increased input price (fertilizer, fuel, etc.) and labor wage has lowered farmer incomes and reduced incentives to adopt yield-increasing technologies. Lack of timely availability and poor quality of seeds and fertilizers have hindered to harness the full potential of improved rice varieties. Similarly, opening up of the world market for rice following WTO is likely to alter the comparative advantages associated with rice production in different parts of Nepal. In this context, it is essential to identify appropriate policy responses to enhance the productivity and sustainability of Nepal's rice-based agricultural system. The importance of informed policy-making in the changing socio-economic context of Nepal is ever increasing.

Socio-economic factors such as lack of improved seeds, lack of inputs such as fertilizers in a timely manner, poor quality of seeds and fertilizers, slow growth of irrigation, limited access to credit, lack of rural infrastructures like road and electricity, and limited marketing facilities for output may also be constraining wider diffusion of technology. For example, irrigation is a prerequisite to adopt high yielding varieties and apply adequate amounts of fertilizers.

Better policies and institutional set up are required to improve timely delivery of quality fertilizers as well as to monitor the qualities of inputs in the market. Access to agricultural credit is crucial for expansion of shallow tubewell irrigation, adoption of modern technologies and market-oriented production. While the financial institutions have substantially increased in Nepal, their penetration at the ground level and farmers' access to agricultural credit is still weak. Policies should support community-based organizations, credit cooperatives, micro-credits, and expansion of formal banking services in rural areas to improve farmers' access to farm credit. Adequately investment on rural infrastructures and markets is essential to increase farmers' access to inputs, to increase adoption of improved technologies and to strengthen farmer-market linkages. Government should formulate suitable programs and policies to overcome these challenges.

In addition to these broader policy issues, there is also an urgent need to analyze the patterns of rice technology adoption in different parts of Nepal and identify constraints to adoption so that effective interventions can be designed. Such interventions may take the form of better design of technology and/or improved policies.

Characterization and understanding of inter-relationships between biophysical and socio-economic factors in determining rice productivity and technology adoption are of critical importance for priority setting, impact evaluation and technology targeting and delivery. However, information currently available on these socio-economic aspects is inadequate and fragmented. Currently, the policy research systems in support of rice production and marketing are not well established in the national agricultural systems of Nepal. As a result, research policy discussions and prioritization are often not supported by adequate analysis. There is a need to establish a socio-economic and policy research support system to address socio-economic and policy issues for increasing rice productivity and sustainability and thus food security in Nepal. Such a research system currently does not exist and the efforts made by different agencies are somewhat piecemeal and fragmented. This component should aim at (a) analyzing the patterns of technology adoption and technology impact in rice-based systems of Nepal, (b) identifying policy interventions needed to improve the profitability of rice production in the context of trends towards globalization, (c) providing an overall socio-economic vision to guide priority setting across major agro-ecological/socio-economic domains on rice research and technology development, and (d) building capacity within NARC and supporting institutions for socio-economic and policy research.

Investment in rice research and extension

Despite very high importance of rice farming on livelihoods and national economy, the investment on rice research is very low in Nepal with only less than 0.1% of the value of rice output being invested in rice research (Gauchan and Pandey, 2011). Government should increase investment for rice research and extension, particularly augmenting research infrastructures and training manpower at all levels. Because of the small market size, the private sector is less likely to make big investment in rice R&D in Nepal.

Many of the technologies available at research stations have not reached the farmers. For example, NARC has released 69 rice varieties but only few are popular among farmers. A typical rice farmer has very low level of education. They lack knowledge and skills in improved farming practices. This warrants effective extension systems to provide knowledge and skills on improved rice farming practices to farmers. The public extension systems are inadequate and ineffective. The public extension workers not only have to cover large geographical area but also need to provide extension services on wide range of subjects. The extension workers certainly appear to be overstretched in terms of workload (IFPRI, 2010). Some of the gaps in extension system have been addressed by private organizations and projects working in agriculture but their coverage is limited. Government should invest to improve public extension system, particularly for capacity building of extension workers at grassroots. The fast development of information and communication technology (ICT) brings opportunities for innovations in agricultural extension system. The government should encourage the private sector to apply ICT and other innovative models in agricultural extension.

Climate change and extreme weather events are increasing posing threats to rice production. Government should invest adequate resources to develop and disseminate climate-smart rice varieties for new climatic conditions.

Capacity building in strategic frontier areas of rice research

The potential of the scientific manpower available at NARC has not been fully utilized. The scientific manpower must be trained on new research tools so that they can contribute to overcome the problems in rice research and sustainable rice production. Besides, there is a serious technology transfer gap from lab to the field, which is partly due to poor linkages among stakeholders. Therefore, effective linkages should be established between NARC and the ministry of agriculture, across departments within the ministry of agriculture, as well as between government organizations and NGOs to implement proven technologies and empower farmers to become partner in the system. Effective extension systems should be used to disseminate the technologies and educate farmers about the new technologies. Also, scientists and extension specialists should be trained in critical areas to implement the national research and technology development/dissemination programs.

Research has shown potential of biotechnology and genetic engineering including heterosis (hybrids vigor) for breaking yield barriers both in favorable and unfavorable environments. Many novel genes & easy methods of gene transfer are now available. Research programs should aim to combine conventional breeding with molecular breeding for genetic enhancement of crop in relation to pest and disease resistant, drought and flood resistant, and nutritional quality improvement. Likewise, rice hybrids have shown potential in other countries especially in rainfed ecosystem. Government should train scientists to work on hybrid rice research. The rice strategy for Nepal should include capacity building program in the key institutions such as NARC on these new plant breeding tools.

Results and Discussion

NARC priority and needs IRRI support

Hybrid rice research and development

Farmers of Nepal are interested to grow hybrid rice and NARC has initiated hybrid rice research in National Rice Research Program (NRRP), Hardinath, Nepal from the rice growing season 2013 with the help of IRRI. IRRI has been sending the hybrid rice materials from Philippines and Scientists from NARC are conducting the research. The flow of hybrid rice materials from IRRI should be continued.

Bio-technology research facilities development

NARC has recently established Biotechnology Division. However, the equipments in the laboratory are limited and trained manpower to run the lab. are also not well trained. NARC do not have sufficient resources for the equipments and providing training on molecular breeding to the scientists for quality research.

Capacity building of scientists and extension workers

Many young scientists are hired by NARC in recent years. They need training in advanced rice research and development. IRRI has been providing such training to Nepalese scientists in the recent years, but this is not enough. Therefore, Their capacity should be enhanced through long-term and short-term trainings, and exposure visits.

Conclusion

Rice production in Nepal faces several challenges. Current rice yields are lowest among all South Asian countries. Despite significant role of rice farming in poverty reduction and food security, the investment in rice research is very low. Hence development and dissemination of improved rice technologies is very poor. As a result, rice yield growth has been negligible in the past two decades. The country which used to export rice in the past, now imports about one million ton of milled rice every year. This poses a serious challenge to rural poverty reduction as well as to food and nutrition security in the country. The problem will become more serious in coming decades. Rice yields must be increased by 3% annually for the next two and half decades if the country aims to meet the domestic rice demand from own production. This is a daunting challenge for policymakers and researchers. The government needs to take this seriously and should make adequate investment on rice research and development so that future food security is ensured. This document identifies some key R&D strategies to increase rice productivity sustainably in Nepal. The broad priorities areas where future rice R&D programs should focus include improved rice varieties, integrated crop and resource management practices, small-scale mechanization, formulation of policies, increased investment in rice research and extension, and capacity building.

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Volume 3 Issue 2 February 2019