Chapter III : Benefits from the international exchange of plant genetic resources

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Key messages

- Foreign sources of genetic resources have contributed more to improvements in major staples, such as rice, wheat, and maize, than to non-staple crops. The benefits to Nepal from future international flows of rice germplasm are estimated to be high.
- Nepal's rate of adoption of rice varieties derived through the multilateral system (MLS) and from other sources, including India and local areas, is high.
- The incremental benefit derived from externally sourced germplasm (50% national, 50% foreign genes) of the Khumal-4 variety is high: about NPR 1.05 billion annually at the current price and the 2010–2012 level of adoption.
- Non-monetary benefits from Khumal-4 are increased production stability as a result of its relatively better disease resistance and non-lodging nature, as well as the ability to grow subsequent crops because of Khumal-4's short growing season.
- Greater investment in plant breeding is needed to incorporate foreign-sourced germplasm into indigenous germplasm to improve productivity and profitability of crops as well as adaptability to changing climate conditions.

Humanity has benefited greatly from the international exchange of genetic resources. In the past, exchanges of plants and animals among farmers, communities, countries, and continents were mainly based on traditional values and customs. Nowadays, the exchange of germplasm is occurring much more frequently. Plant breeders use genetic materials that have been improved by other professional breeders and landraces that are selected and maintained by farmers. They use germplasm developed for environments similar to their own or for new target environments (Maredia and Byerlee 1999, Evenson et al. 1979). In the crop improvement chain, spillover effects occur at several nodes, which complicates precise calculation of the economic benefits of germplasm exchange.

Modern varieties, developed using germplasm acquired through the multilateral system (MLS), can produce good yields and the benefits can be estimated by comparison with local varieties of the same crop. However, differences between modern and "control" varieties are partly confounded by crop management effects, as the performance of modern varieties is often influenced by new crop management practices, farmers' experiments, different use of inputs, irrigation technology, and the incidence of diseases and pests. Changes in climatic conditions can further compound performance differences.

Investment in crop breeding generates appealing rates of return (Echeverria 1990, Alston et al. 2000, Evenson 2001). The major benefits come from increased yield, higher-quality grain, decreased cost of crop management, increased fodder production, and shortened growing season. Such benefits stem from better responses to fertilizers, irrigation, and management; increased resistance to diseases and pests; and increased tolerance of stresses, such as unfavourable temperature, drought, and water logging. Thus, the exchange and use of plant genetic resources (PGRs) are important for food security and adaptation to climate change. The role of PGRs from around the world in developing high-yielding varieties and combating food insecurity is detailed in chapters 1 and 2.

Increasing resistance to heat and drought (Mortimore and Adams 2001, Howden et al. 2007, Phiri and Saka 2008, Asfaw and Lipper 2012), as well as the development and adoption of new cultivars, is necessary to adapt crops to climate change and increase food production (Rosegrant and Cline 2003). Breeding resistant varieties requires access to a large pool of parent materials, which is possible only through international exchange of genetic materials, as no country is self-sufficient in PGRs (FAO 2004).

Article 13 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) clearly recognizes the benefits of facilitated access to PGRs for food and agriculture, which are included in the MLS. According to the ITPGRFA, the benefits accruing from such PGRs shall be shared fairly and equitably. To verify whether sharing takes place, quantification of the benefits and measurement of contributions are warranted. Literature relating to the empirical estimation of economic benefits of the international exchange of PGRs for a given country or region is very limited. In Nepal, no such studies have been carried out to date. Thus, in this context, we aim to assess the economic benefits of improved varieties of selected major food crops developed using foreign PGRs made available through international exchange under the MLS.

We identify popular new varieties that have been most facilitated by international exchange, analyze adoption patterns, and assess the benefits accruing to Nepal. The research questions we address are: What new varieties of key food crops have resulted from international PGR exchange? What have been the dissemination and adoption patterns of these new varieties? What benefits would be foregone in the absence of these new varieties?

Concepts and context of benefits

Benefits of the international exchange of PGRs under the MLS can be grouped into three types: non-monetary benefits, indirect monetary benefits, and direct monetary benefits (**Figure** 3.1). Non-monetary benefits include facilitated access and exchange of PGRs and related information. They also include support of technology transfer, capacity building, production stability brought about by genetic resources, and protecting the rights of farming communities to genetic resources. Indirect monetary benefits include a reduced transaction cost for the exchange and use of PGRs using a Standard Material Transfer Agreement (SMTA) rather than the cumbersome process of accessing material through bilateral systems. They also include real value-added benefits arising from facilitated access, use, and exchange of PGRs in plant breeding in the country and around the globe. Direct monetary benefits are those generated from the access to and exchange and use of PGRs; these include license fees, payment of royalties, up-front payments, and milestone payments through access to PGRs under the SMTA with the payment to the ITPGRFA's benefit-sharing fund.

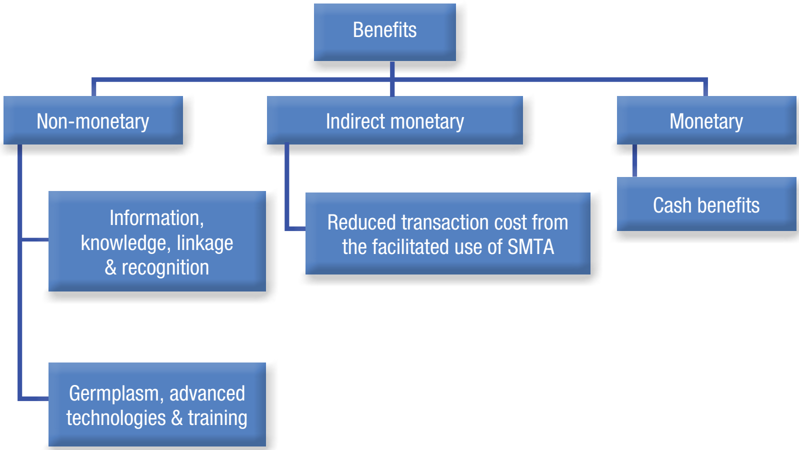

Figure 3.1. Potential benefits to Nepal of sharing plant genetic resources voluntarily under the multilateral system.

Under the provisions of the ITPGRFA, monetary benefits can include either mandatory payment of 1.1% of the gross sales (minus 30% of the cost to cover marketing) if the product is not available without restriction or, alternatively, a payment to discounted rate of 0.5% of the gross sale value regardless of whether the material is available freely or not. However, direct monetary benefits are yet to be realized globally. Evidence shows that the real value-added benefits arising from facilitated access, use, and exchange of PGRs in plant breeding in the country and around the globe can be high. Evenson and Gollin (2003) report the potential for high economic benefits from plant breeding research, particularly through incorporation of genes from international sources into national programs. Hossain et al. (2003) estimate annual gains from adoption of improved rice varieties in Asia at about US$10.8 billion — nearly 150 times the annual investment in rice research made by the International Rice Research Institute (IRRI) and the Nepalese Agricultural Research System together. The rate of return from wheat breeding research, particularly from the flow of international germplasm into Nepal, is also estimated to be high. Morris et al. (1992) estimate an internal rate of return of 85% from wheat breeding research in Nepal that used improved wheat germplasm from international sources between 1960 and 1995. Pant et al. (2011) report that rice consumers in Nepal value the aromatic traits of international rice varieties much higher than the taste-related traits of locally available landraces (US$153 million versus US$28 million per annum).

A recent study by the Australian Centre for International Agricultural Research on improvements in rice yields (1985–2009) from using germplasm supplied by IRRI to three East Asian countries (Philippines, Indonesia, and Vietnam) indicate a high economic rate of return and average increases in yield of 11.2% a year. These gains were mainly the result of the development of high-yielding varieties from externally sourced germplasm (Brennan and Malabyabus 2011). The economic value of this yield increase was estimated US$1.46 billion a year across the three countries.

Methods

We assessed the economic benefits of the international exchange and flow of germplasm of key improved varieties of rice. We carried out a literature review, held consultation meetings with plant breeders and other researchers from national commodity research programs, and conducted field surveys and case studies. The literature review and initial expert consultations helped to identify popular rice varieties that have benefited from the international exchange of germplasm. These include the most popular rice varieties, Radha-4 and Sabitri grown in the terai and Khumal-4 in hills and mountains. Khumal-4 was selected as a case study for assessing economic impact, as it was developed from both external (e.g., IR-28) and indigenous PGRs (e.g., Pokhreli Masino).

Pedigree analysis of the Khumal-4 variety was carried out to identify and track the source of major genes and identify the extent of external PGRs incorporated into this widely adopted variety.

To obtain information about area planted, adoption, and yield, we reviewed and analyzed household adoption data from the Socioeconomics and Agricultural Research Policy Division (SARPoD) of the Nepal Agricultural Research Council (NARC). This information was collected mainly through the IRRI-supported projects Tracking Improved Varieties in South Asia (TRIVSA), Stress-tolerant Rice for Africa and South Asia (STRASA), and Seed-net. Some supplementary information was also collected through a field survey. Comparative data on the yields of both improved varieties derived from foreign-sourced germplasm and an existing local variety without foreign-sourced germplasm were collected and analyzed. We estimated the incremental economic benefits to Nepal from the flow of improved varieties containing genes from external/international sources. We compared adoption area, yields, and price data for varieties derived from foreign-sourced versus locally sourced germplasm.

Selection of rice for the case study

We selected rice for the case study because it is the principal crop in Nepal. It is grown on about 1.5 million ha of land, or about half the net cultivated area of the country and accounts for a fifth of the agricultural GDP. Rice is the most important cereal crop in terms of cultivated area, production, and livelihood as it supports over two-thirds of farm households. Rice also supplies about 40% of the food calorie intake of the people of Nepal with average per capita consumption at 122 kg per annum (MoAD 2013).

Economic framework for estimating benefits

Economic surplus can be used to measure an area affected by incorporation of genes from foreign sources through a plant breeding program either indirectly (in the form of a shift in the supply curve, which implicitly reflects changes in area planted) or directly (by estimating the rate of adoption of modern varieties derived from external sourced germplasm and applying this rate of adoption to the area planted to the crop). The main advantage of using this method is that it requires less information than other models (Alston et al. 1998, 2000) and permits the estimation of economic benefits from the adoption of an innovation (new variety), compared with the situation before adoption (only traditional varieties available) (Morris et al. 1992).

Benefits over the base area were estimated using the conventional method of multiplying genetic gains attributable to modern varieties (in this case, the yield losses foregone) by the area planted with varieties derived from foreign-sourced germplasm. The benefits that would be foregone in the absence of the innovation provide a measure of the opportunity cost of not engaging in international PGR exchange.

Parameters needed to calculate the value of additional production

Once the area planted with Khumal-4 was estimated, the productivity gains of Khumal-4 over its original parent Pokhreli Masino were assessed. Three key parameters were needed: the area planted with modern varieties, the productivity gains attributable to adoption of the modern varieties, and the price of rice. Using a simple economic surplus model, these three parameters were combined to calculate the value of additional production in a given period (*t*):

$$B_t = A_t (Y_t - C_t) P_t$$

Where, *B* is the value of additional production attributable to rice breeding using foreign-sourced germplasm; *A* is the area planted with the rice variety developed using foreign-sourced germplasm; *Y* is the yield gain attributable to the new variety; *C* is the additional cost of production of the new over the traditional variety expressed in rice equivalents; and *P* is the farm gate price of rice of the designated variety, all over time *t*.

The average yield of Pokhreli Masino obtained during the field survey was compared with that of Khumal-4 to estimate the productivity gain attributable to adoption of Khumal-4. Using the farm gate price of both varieties obtained during the field survey, the net additional value (in NPRs) was estimated for rice-breeding research using international genes.

Pedigree analysis

In 2013, the country had 69 released rice varieties (MoAD 2013). Most were obtained from the International Rice Research Institute (IRRI) through the International Network of Genetic Evaluation of Rice (INGER) and were released directly or used as parents for developing new varieties. A few were selected from popular local landraces in Nepal. Pedigree analysis of popular rice varieties revealed that 68% of the varieties released in Nepal since the beginning of the variety development process came from foreign sources (**Table** 3.1).

The pedigree analysis of Khumal-4 is presented in chapter 2 (**Figure** 2.7). Khumal-4 was developed by crossing the popular exotic rice variety IR-28 with the popular indigenous Pokhreli Masino, which has unique grain qualities (good taste, fine grains, taller plant height, and local adaptation). Khumal-4, which was released in 1987, is intermediate in plant height and combines the high yield and disease tolerance of IR-28 with the grain quality and straw yield of Pokhreli Masino. IR-28 was originally developed in IRRI from many crosses using germplasm from Taiwan, India, Indonesia, Thailand, and the United States. It has a dwarf gene from the DGWG variety (Taiwan) and the high-yield trait of IR-8 (IRRI). It is most popular among farmers in the mid-hills (800–1500 m above sea level) of Nepal and among consumers in Kathmandu Valley.

Table 3.1. Contribution of foreign-sourced germplasm to popular rice varieties in Nepal

Category	No. and name	Source of germplasm		CGIAR (MLS) and bilateral flow
		Nepal (%)	Foreign (%)	
All improved varieties released	68 (released) +1 (registered)	32	68	Mostly IRRI
Improved varieties with all genes acquired through MLS	Sabitri, Radha-4	0	100	IRRI (MLS)
Improved variety with 50% genes through MLS	Khumal-4	50	50	IRRI (MLS) + Nepal
Improved varieties with foreign-sourced genes but non-MLS	Sona mashuli, Sarju-52	0	100	Cross-border informal flow from India
Improved varieties with all domestic genes	Lalka basmati, Jethobudho	100%	0	0

Farm-level adoption of improved varieties

Household survey data collected under IRRI's TRIVSA project were analyzed to identify the extent of adoption of improved varieties derived from the MLS. The study was carried out from 2010 to 2012 in various ecological zones and development regions of Nepal by the Socioeconomics and Agricultural Research Policy Division of NARC (Velasco et al. 2014, Gautam et al. 2013). Analysis showed that 87% of the total area under rice in 2010–2012 was planted with improved varieties (Gautam et al. 2013, Gautam and Gauchan 2013) developed with parent germplasm obtained from formal international sources (IRRI) and informal cross-border flows from India. This finding is consistent with those of earlier household surveys, the STRASA project (Gauchan et al. 2012), and government statistics (MoAD 2011).

The findings of the TRIVSA survey of 1160 farmers in 29 districts of Nepal indicate that great variation exists in the extent and pattern of adoption of varieties in different agro-ecological zones and development regions of the country. The degree of adoption of modern varieties is very high in the terai (97%), moderate in the hills (65%), and very low in mountain regions (12%).

According to our data, 57% of the rice area in Nepal is under improved varieties derived from genetic resources received through the MLS, mainly from IRRI (**Figure** 3.2). These include popular varieties, such as Radha-4, Sabitri, Hardinath-1, and Masuli. Improved varieties derived from India through informal cross-border flows occupy 38% of the rice area. The dominant varieties here include Sona mashuli, Kanchhi masuli, Samba masuli, Sarjoo-52, and Ranjeet.

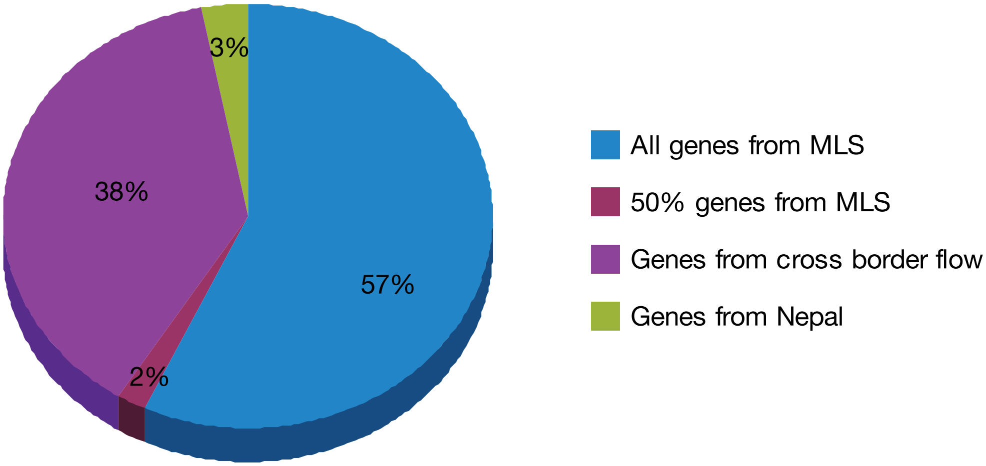

Figure 3.2. Farm-level adoption of germplasm derived through the MLS and other sources in Nepal.

About a dozen rice varieties are dominant in Nepal, but their popularity varies by region. Sona mashuli is the number one variety, accounting for 13% of the area planted with modern varieties mainly in the central terai, followed by Radha-4 (12%) mainly in western and mid-western regions. Kanchhi masuli is dominant in 9% of the total modern varieties area, but confined to the eastern terai region. Sabitri covers 6% of the total modern variety area and is popular in both terai and lower hills (below 700 m elevation). Khumal-4 is commonly grown in at 900–1500 m in the upper mid-hills and mountain regions (2% of the total modern varieties area), but over 9% in the mid-hills region and 7% in the high hills. The findings also indicate that about 20 varieties were being adopted in more than 1% of total modern varieties rice area in Nepal during 2010–2012.

Extent and pattern of adoption of Khumal-4

Incidence and intensity are two widely used indicators of adoption. Incidence of adoption is the percentage of farmers growing modern varieties at a specific time, whereas intensity of adoption is the percentage of area planted to modern varieties (Gauchan et al. 2012). We used intensity, i.e., percentage area of Khumal-4 at the farm level, as an indicator of adoption for this study.

Adoption reflects farmers' decision to incorporate modern varieties into their production system by replacing traditional varieties or replacing improved varieties of older vintage. Available survey data revealed that the extent and pattern of adoption of Khumal-4 varied across districts in Nepal (Gautam et al. 2013).

Khumal-4 was developed and recommended for altitudes of 800–1500 m. Hence, it was mainly adopted by farmers in the mid-hills and lower parts of mountainous districts. Of 29 districts surveyed in 2010–2012, Khumal-4 was found in 9 of the 16 hill districts (Kavre, Bhaktapur, Dailekh, Lamjung, Parbat, Myagdi, Kaski, Gorkha, and Baglung) and one of the two mountain districts (Sankhuwasabha) (**Figure** 3.3). The highest rate of adoption was found in Bhaktapur, Kavre, and Dailekh districts. Khumal-4 was not reported from Jumla, a high-mountain district nor in some of the hill districts (e.g., Udayapur) where the rice-growing area is at lower altitudes (< 800 m), in river basins and lowland valleys. No farmers in terai districts have cultivated Khumal-4.

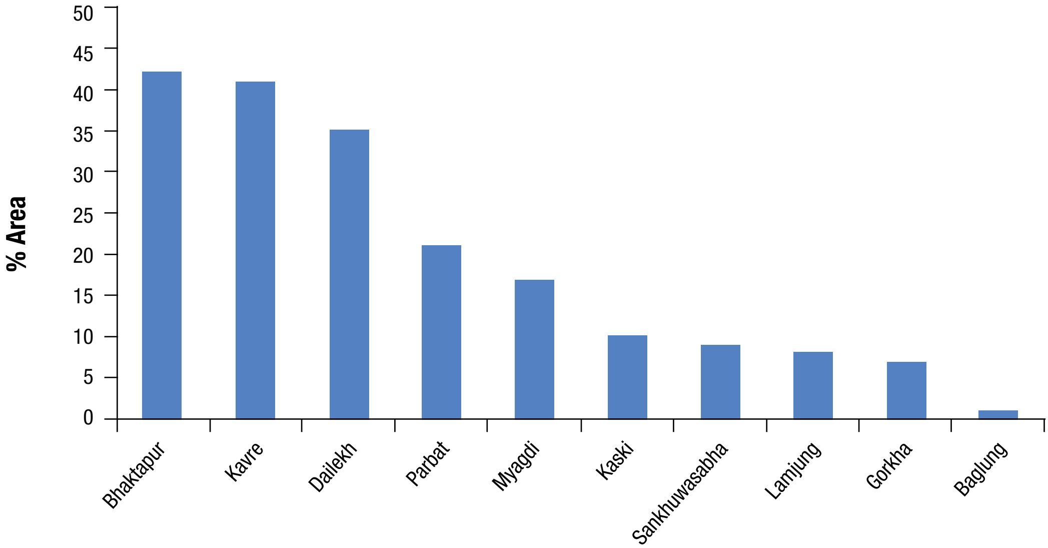

Figure 3.3. Percentage of rice-growing area planted with Kumal-4 in nine hill and one mountain (Sankhuwasabha) districts.

Source: Field survey; Tracking Improved Varieties in South Asia data (2010–2012).

Estimating the economic benefit from Khumal-4 rice

Area planted with Khumal-4 rice

To estimate the economic benefits of a given variety, we must have farm-level data on coverage of that specific variety. Official data on average rice area for the three years of the survey period (**Table** 3.2) indicate that Khumal-4 was planted on 35856 ha in the hills region and 4659 ha in the mountains. This accounts for about 9% and 7% of the total rice area in those regions for a total of more than 40 thousand ha covered by Khumal-4 during the study period.

Table 3.2. Average area devoted to rice crops (2009–2011) and estimated Khumal-4 coverage

Region	Rice area, ha			3-year average, ha (% of total)	Khumal-4 coverage, ha (% of rice area)
	2009	2010	2011		
Mountain	64915	66713	68051	66560 (4)	4659 (7)
Hill	392664	407037	395492	398398 (26)	35856 (9)
Terai	1098361	1022726	1067950	1063012 (70)	0
All	1555940	1496476	1531493	1527970 (100)	40515

Sources: MoAD (2011) and NARC TRIVSA field survey (2010–2012).

Value of increased rice production

Table 3.3 shows comparative yields of Khumal-4 and Pokhreli Masino and an estimate of the benefits of growing Khumal-4 in Nepal. There is a clear yield gain when farmers switch from the traditional Pokhreli Masino variety to Khumal-4, as the latter yields about 1.5 t/ha more than the traditional variety. However, the cost of production of Khumal-4 is relatively higher (rice yield equivalent of 1.25 t/ha) as compared to Pokhareli Masion (rice yield equivalent of 1.0 t/ha). Estimating yield in terms of cost in rice yield equivalents for both varieties by adjusting with production costs, the net yield gain from adoption of Kumal-4 remains at 1.25 t/ha.

Although all costs associated with PGR transfer and breeding, mostly within public-sector institutions, are not included in our analysis, part of those costs are included in the price of seeds sold by breeding institutions. The costs of seed multiplication and marketing, mostly within the private sector, are automatically included in seed prices and reflected in cost of production.

In terms of net revenue, the additional revenue from growing Khumal-4 was NPR 26250 (US$275) per hectare. Based on analysis of total area planted with Khumal-4 in 2010–2011, the gain was NPR 1.05 billion (US$11 million). Although this estimate is somewhat crude, we conclude that there are economic benefits from incorporation of Khumal-4, despite its relatively low adoption rate in the hill and mountain regions of Nepal.

Table 3.3. Increased yield and revenue gained from growing the modern Khumal-4 variety compared with the traditional Pokhreli Masino variety in Nepal

Variety	Average yield (t/ha)	Yield in terms of rice cost equivalents* (t/ha)	Net yield gain from adoption (t/ha)	Farm gate price (NPRs/t)	Revenue (NPRs /ha)
Khumal-4	3.50	1.25	2.25	25000	56250
Pokhreli-Masino	2.00	1.00	1.00	30000	30000
Difference	1.50	0.25	1.25	-5000	26250

* Estimated equivalent rice yield from actual cost of production data.

Note: During this study, 95.5 Nepalese rupees = 1 United States dollar.

Khumal-4 also provides other benefits that we have not included in the above estimate. These include production stability as a result of disease tolerance and less lodging compared with Pokhreli Masino. Its shorter growing season also enables farmers to increase cropping intensity by cultivating vegetables and cash crops.

Considering that 68% of rice varieties released in Nepal contain genes of foreign sources (chapter 2), the benefits from the transfer of rice genetic resources from foreign sources are great. Many other crops grown in Nepal also carry genes from foreign sources, in particular wheat, maize, pulses, and vegetables. Even such crops as soybean and sugarcane grown in Nepal, although not included in Annex I of the ITPGRFA, have benefited from genetic resources of foreign origin.

Conclusions and implications

This study estimates the economic benefits of the adoption of improved germplasm at one point in time. Estimates over longer periods would have allowed more accurate measures, such as net present value and internal rate of return. Accounting for the benefits of innovations in crop varieties requires detailed disaggregated data for adoption rates, yields, prices, and farm-level information as well as complex analytical methods, econometric techniques, and statistical tools. Considering resource and time constraints, this study used available data and simple calculations to estimate the benefits of easy access and use of PGRs from international exchanges.

Major staples, such as rice, wheat, and maize, have benefited more from foreign sources of genetic resources than non-staple crops. Our case study of rice demonstrates that adoption of varieties that include parents obtained through the MLS and other sources (cross-border flows from India and local origins) in Nepal is high. This suggests that future benefits from the international flow of germplasm in rice could also be high.

The use of foreign-sourced germplasm to develop Khumal-4 provides annual benefits of about NPR 1.05 billion at the current price and the 2010–2012 adoption level. Non-monetary benefits include production stability and the ability to grow additional crops on the same land. If Khumal-4 had not been developed and promoted, the country would have lost these substantial monetary and non-monetary benefits, implying a high opportunity cost of not engaging in international PGR exchange.

Considering the great benefits accruing from easy access to foreign-sourced germplasm, facilitated access under the MLS is important to promote and sustain variety innovations in developing countries like Nepal, where agriculture is critical to food security and the livelihood of the people. Moreover, there is a need for more investment in plant breeding by incorporating foreign sourced germplasm in the existing indigenous germplasm to improve productivity and profitability of the crop as well as to improve adaptability of farming systems to changing climate conditions.

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