This brief aims to create more awareness that no country is self-sufficient in plant genetic resources and that international exchanges have facilitated critical variety innovations in individual countries contributing significantly to agricultural productivity enhancement. The brief synthesizes eight national country studies on the interdependence and flow of plant genetic resources (or the dynamics of the global crop commons) carried out under the project Strengthening National Capacities to Implement the International Treaty on Plant Genetic Resources for Food and Agriculture coordinated by Bioversity International.

The eight countries highlighted in this brief have become highly interdependent relying heavily on external genetic resources for the introduction and improvement of most of their major food crops and agricultural development overall. In order to be able to adapt to climate change it is expected that this interdependency will further increase. Locally available germplasm may no longer be suitable and ‘novel’ germplasm may need to be accessed from sources elsewhere around the globe.

No country is self-sufficient when it comes to plant genetic resources: the cases of Bhutan, Burkina Faso, Costa Rica, Côte d’Ivoire, Guatemala, Nepal, Rwanda and Uganda

A synthesis compiled by Ronnie Vernooy and Evelyn Clancy

Through facilitated exchange of germplasm across borders, agricultural development can continue, crop diversity can increase and countries can achieve food security.

This strong interdependence between countries provides a key rationale to make good use of the multilateral system of access and benefit sharing under the International Treaty on Plant Genetic Resources for Food and Agriculture. Plant breeders and agricultural scientists are generally well aware of the nature and extent of this kind of interdependence in different crop breeding programmes. However, other stakeholders, such as farmers, policymakers, civil society organizations, departments of environment, may have only limited information on the role played by international exchanges of plant genetic resources in the development of agricultural innovations.

1 We acknowledge the authors of the country studies that we used for this compilation (see page 8).
Bhutan

Rice, maize, wheat, barley, buckwheat and millets are the major cereal crops cultivated. The country’s dependence on foreign sources of germplasm is very high. Introduced varieties of the major crops tested and released in the country are gradually displacing the traditional landraces.

Although there are no precise historical records of its introduction, rice must be one of the earliest cultivated food crops in Bhutan. The first introduced modern rice variety was a Japonica variety named No 11 from Japan in 1968. New rice germplasm started to flow into the country in 1984 when collaboration with the International Rice Research Institute (IRRI) was established. The flow of rice germplasm continues averaging about 300 new breeding lines and varieties from IRRI per year. Later, the flow of maize germplasm began through links with the International Maize and Wheat Improvement Center (CIMMYT) and every year about 100 new materials are brought into the country for testing on station and on-farm. New germplasm of wheat came to Bhutan as early as 1972 in the form of Sonalika, one of the most successful varieties of the Green Revolution. Wheat germplasm has also come in from neighbouring countries like India and Nepal. New germplasm of millets from India and barley from the International Center for Agriculture in the Dry Areas (ICARDA) have been introduced.

As of December 2015, a total of 46 different crops and 297 varieties have been introduced and imported into the country. The new crops include subtropical fruits and nuts, vegetables, cereals, oil crops and grain legumes. Recently, germplasm of various citrus like mandarin, lime and lemon for testing as well as for rootstock purposes has been acquired mainly from Europe, Japan, Thailand, Australia and India. The country also has imported new germplasm of non-traditional crops like mango, avocado and olive. Pakistan, India, Nepal, Japan and Bangladesh are the major sources of germplasm for oil crops and grain legumes.

Burkina Faso

The main crops are millet, sorghum, maize, rice, groundnut, fonio, soybean, yam, cowpea, potato, sweet potato, cassava, tomato, onion and cabbage. An estimated 23% - 32% of its crops have been introduced from outside of the country and the West African region. The breeding and improvement of native varieties such as millet, cowpea, yam, bambara groundnut and sorghum, which disappeared from Burkina Faso, have also benefitted from the re-introduction of the country’s own germplasm and foreign-sourced germplasm, often mediated through international institutions such as the CGIAR, e.g. IRRI has provided Burkina Faso with rice germplasm from at least 17 other countries.

Costa Rica

The main crops grown are white maize, rice, beans, tomatoes, potatoes, cassava and onions. There has been a consistent dietary shift towards rice, wheat, soybean and plantain making the country more dependent on non-native crops compared to other Central American countries. Since the 1980s, cash crops for export such as banana, pineapple and coffee have been introduced. Tracing back the history of domestication of rice (an introduced crop) and bean (native), highlights Costa Rica’s dependence on other countries’ germplasm.

Today, rice and beans are the main ingredients of the nation’s flagship dish, ‘el Gallo pinto’, in which they are cooked together.

Rice seeds of the Japonica variety were introduced into Central and South America by European traders (mostly Spanish) between the 16th and 18th centuries. Further exchanges of material occurred among countries in Central, South, and North America. There have also been findings of the African cultivar in Central America, most likely as a result of introduction during the time of the transatlantic slave trade. The earliest reports of rice cultivation in Costa Rica are from Matina, a hilly area close to the Atlantic coast (in 1737), and Esparza, on the Pacific side of the country (in 1788). Four domesticated bean species grow in Costa Rica (P. vulgaris, P. lunatus, P. coccineus, P. dumosus) and over the past 20 years, 22 wild bean populations have been identified in the country.

Costa Rican rice and bean research institutions have long been collaborating with national and international organizations involving germplasm exchanges. This is reflected both in the presence of rice and bean germplasm of Costa Rican origin in international genebanks and in the diversity of materials from foreign countries that have been introduced into the country through these genebanks. Between 1979-2009, at least 99 rice accessions were introduced to Costa Rica from IRRI, having been originally collected in at least 29 countries. Another source of introduced rice is the Fondo Latinoamericano para Arroz de Riego (FLAR), a public-private consortium. Ten FLAR varieties were released in Costa Rica between 2006 and 2010. A pedigree analysis of the successful rice variety Palmar 18 released in 2006 identifies genetic resources originally collected or improved in at least eight foreign countries: China, Indonesia, Malaysia, Myanmar, the Philippines, Taiwan, Vietnam and the United States.

From 1982 to 2007, collaboration between the bean research network PROFRIJOL and the International Center for Tropical Agriculture (CIAT) led to the release of 21 improved varieties of beans in Costa Rica. Most of the released varieties, be they hybrids or not, incorporate germplasm originally collected in El Salvador, Colombia, Brazil, Guatemala, USA and CIAT. Amadeus 77, a variety released in Honduras, was evaluated and adapted to Costa Rican conditions between 1999 and 2003, both at experimental stations and in farmers’ fields, and then released as Cabecar in 2006. Cabecar is used today in almost 90% of the bean-growing areas of Costa Rica.

Photo: Farm worker leaning on a banana plant. The cooking bananas, which belong to a locally domesticated group called East African highland bananas, are intercropped with beans and cassava. The farm is located in southwestern Uganda, the country’s main banana-growing region.
**Côte d’Ivoire**

The country’s main crops in terms of agricultural production are yam, cassava, rice and plantain. These four crops are the staples of the majority of the population. The original sources of germplasm of all four crops are located outside the country. Novel breeding material to improve the collections of existing varieties has also come from abroad to a significant degree.

In the case of yam, the government has authorized a single organization, l’Agence Nationale d’Appui au Développement Rurale (the national organization in support of rural development, ANADER), to distribute (new) yam varieties. New varieites are developed by a number of research organizations such as the Centre National de Recherche Agronomique (the national centre for agronomic research, CNRA). In the last few decades CNRA has decreased the use of foreign germplasm in favour of material already in the country. CNRA and ANADER have collaborated to distribute important domesticated varieties such as Kponan and Krenglé as well as improved varieties such as CivC Da 053 and Civ Cd r 015 which are used by many farmers.

In the case of cassava, new breeding material from abroad is regularly crossed with local material and then field tested for several years. For example, in the last two decades more than 20 varieties including TMS4(2)1425, TMS30572 and I88/00158 have been systematically crossed and field-tested. Some of the new varieties resulting from the crosses, such as IM93, have not been well received by farmers while others, such as CM52 (better known as Bocou 1), have been adopted by many farmers.

Rice has a very high dependence on foreign germplasm. Since 2011, the country has yearly field-tested a number of promising rice lines with regard to drought tolerance in rain-fed conditions and tolerance to iron toxicity in lowland conditions. By 2015, CNRA had tested about 150 new lines. This is an area of research of increasing importance given the climate changes the country is experiencing in particular leading to an increase in drought.

In the case of plantain, new germplasm arrived in the form of improved varieties such as the FHIA 21 hybrid (developed in Honduras) and BITA 3 or PITA 3 hybrid (developed in Nigeria based on a cross of a variety from the Philippines and a variety from an unknown country).

**Guatemala**

The main crops cultivated are maize and beans, followed by wheat, sorghum, potatoes and faba beans. Coffee, sugarcane and bananas are grown for export and since the 1990s, government agricultural policies have promoted the growing of non-traditional crops (such as snow pea, broccoli, cauliflower and melon) for export. Although Guatemala is part of the Mesoamerican centre of maize and bean diversity it has greatly benefited from the exchange and introduction of foreign germplasm for the improvement and adaptation of these two crops.

Since 1972, the Instituto de Ciencia e Tecnologia Agricola (ICTA) has been undertaking research and breeding for both maize and beans, together with Guatemalan universities. They have received maize and bean germplasm for their breeding programmes from other countries, mostly through international institutions such as CIMMYT and CIAT. Most of the maize materials are of Mesoamerican origin but they also include South American, Asian and African samples. Bean accessions are almost all landraces or traditional cultivars. While some of these materials were originally sourced in the country itself, the majority came from other Central American countries, mostly from Mexico and other countries across the globe.

Regional programmes such as the maize research network PRM and the bean research network PROFRIJOL have facilitated a consistent release of new varieties that incorporate materials from international sources. Between 1991-1996, 43 new maize varieties were developed; between 1978-1998, 17 bean varieties were released, with material pre-bred at CIAT; and between 2010-2011 another 6 bean varieties were released.
A pedigree analysis of ICTA Ligero, one of the most successful bean varieties released through PROFRIJOL, shows it has been developed through crosses obtained from Mexico, El Salvador, Nicaragua and Colombia. ICTA Hunapu is based on a cross between a Guatemalan traditional variety (Negro Pacoc) and a line produced from crossing Brazilian and Mexican materials.

**Nepal**

There is little documentation on the origins of crop domestication in the country. However, an in-depth study, including pedigree analyses of four major crops – rice, wheat, lentils and potatoes – highlights Nepal’s dependence on foreign-sourced germplasm for its agricultural research and development (including breeding) and ultimately, for its food security.

Rice is the most important staple food crop in Nepal and has been grown since 1500 BC. The southeast Himalayan region, including Nepal, is considered a centre of diversity for this crop. The co-existence of four wild rice species and wild relatives and cultivation of many on-farm landraces provide a high degree of genetic diversity and an important gene pool for rice research in Nepal and elsewhere. Research on local rice varieties began in 1951. Varieties from Japan, Philippines, India, USA, Taiwan and IRRI have been introduced. Hybrid germplasm from IRRI, China and India has also been tested with the best varieties being registered for general cultivation. Pedigree analyses of 20 improved varieties of rice indicates that a total of 47 ancestors (landraces) originating in 12 countries, mainly in Asia, were used to develop these cultivars.

It is believed that wheat was introduced to Nepal in the 16th or 17th century from India and many landraces are still grown. Cultivated landraces of wild relatives and diploid species of wheat are also found in Nepal. Wheat breeding intensified in the 1960s with the introduction of several varieties from India and elsewhere which led to the release of the first improved cereal variety Lerma-52. In 1965, Mexican semi-dwarf varieties were introduced in a ‘grow more wheat’ campaign. Nepalese breeders used parent material obtained through CIMMYT and gene pools with pest and disease resistance from Brazil, Zambia, China and CIMMYT to develop elite lines which have been distributed internationally. Pedigree analyses of the 35 modern wheat varieties in Nepal show that all ancestors and landraces were from other countries and international organizations.

A collection of 171 lentil landraces from Nepal are conserved in the national genebank. However, the use of Nepalese landraces in the breeding programme is minimal. About 95% of lentil breeding materials in the National Grain Legume Research Programme are genetic resources received from external sources especially ICARDA. Since 1977, Nepal’s breeding programme has introduced ten new varieties for cultivation, developed using Nepalese landraces and genotypes of South Asian origin, introduced from India and Syria.

In 1793, potatoes were introduced into Nepal. In the 1950s and 60s, Nepal received support from the International Potato Center (CIP), Peru to accelerate its potato research programme through experimental trials and seed production. The earliest cultivar, Kufri Jyoti, was introduced from India in the 1960s. In the last 25 years, ten potato varieties have been released, using mainly exotic germplasm including from Germany. Although there are many unique landraces of potato in Nepal, not a single one has been found in the pedigree of released varieties.
Rwanda

Rwanda’s agriculture is characterized by very diversified food and forage species, the majority of which originate outside the country. The history of the introduction and evolution of crops and forages is not well documented. There are no good data on recent in and outflows of germplasm, but some data collected from 1980-2010 indicate that germplasm entering Rwanda concerns mainly sweet potato, Irish potato 2 and rice while the germplasm outflow concerns mainly sorghum, common beans and sweet potato.

Some crops such as sorghum, finger millet and pumpkin are thought to be traditional since they are mentioned in different stories from the 12th -13th centuries. Other crops such as maize, beans and sweet potato were introduced later, between the 15th - 18th centuries; beans by the Portuguese in East Africa. The first wheat germplasm was introduced around 1970 from CIMMYT and national programmes of Burundi, Kenya, Tanzania, Uganda, Ethiopia, Zambia, Mexico, Canada, USSR and Turkey. Although precise information on sorghum germplasm flows before the 1994 war and genocide in Rwanda is not available, the sorghum research programme of the former ISAR (now Rwanda Agriculture Board - RAB) carried out extensive germplasm collections both nationally and internationally (mainly introduced from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT-Kenya). The programme maintains more than 200 varieties.

Soybean was introduced in 1930 and different varieties adapted well to different agro-ecological zones. Cassava was introduced at the same time as soybean by European missionaries. New cassava germplasm has since mainly come from IITA and CIAT. Sweet potato and Irish potato, the two major tuber and root crops in Rwanda were introduced in the 18th and 20th centuries respectively by the Rwandan army during the war of conquest and by missionaries. More recently, Irish potato varieties were obtained from CIP, Libramont-Belgium and CIP-Uganda. In 1979 the national potato research centre was established. The first six new potato varieties were released in 1983.

Coffee, now the main cash crop, was introduced before 1920 by the first missionaries; most of the materials originated from Ethiopia and DRC (former Zaïre, Kivu Provinces). Coffee research started in 1930. Research largely targets coffee germplasm from Ethiopia and Brazil. Tea research started in 1958 and tea varieties came from DRC, Burundi and Kenya. Pyrethrum research started in the 1950s; germplasm was mainly introduced from DRC. Horticulture research started in the 1930s. Apple was introduced in 1982 from Zimbabwe. Several banana varieties were introduced from DRC; research started in 1953. Very little is known about when and how forage species entered the country. Some research has been going on since the 1980s.

2 In Rwanda and Uganda, Irish potato refers to any potato variety other than sweet potato.
Uganda

The country’s main staple foods are bananas, maize, cassava, millet, sweet potatoes, yam, rice, pumpkin, beans and sorghum. Most of these crops have their origin elsewhere and were introduced in previous centuries by navigators, traders and soldiers. After Uganda became a British protectorate in 1894 agriculture was modernized and novel crops such as tea, coffee, sugarcane, Irish potatoes and cotton were grown, mostly for export.

Banana cultivation in Uganda likely goes back 2000 years. Bananas originated from the area stretching between India and the Solomon Islands - considered the primary centre of domestication of the crop. Uganda is a secondary centre of diversification of the East African highland bananas. Banana research and breeding in Uganda are of recent date led by the National Agricultural Research Organization (NARO) with support of IITA and Bioversity International. A number of new varieties originally developed in Honduras were officially released. At present, research organizations are evaluating new hybrids known as NARITAS.

The cultivated bean species was introduced to Eastern Africa by Portuguese traders in the 16th century. Two distinct gene pools, Andean and Mesoamerican, make up the genetic pool complemented by introgressed types which are common because farmers use mixtures. The first bean breeding activities in Uganda started in the 1960s led by the National Crop Resources Research Institute (NaCCRI) with support from CIAT and more recently, the Pan African Bean Research Alliance (PABRA). To date, more than 20 new varieties have been released.

Maize was introduced by the Portuguese along the East African coast in the mid 16th century to provision their garrison at Mombasa. In the 20th century several new maize varieties came from the USA via Kenya, South Africa and Tanzania. More recently, a high altitude variety came from Peru. Other recent introductions of new varieties (in particular hybrids) in Uganda have been through breeding programmes based in Kenya.

Cassava, whose centres of origin are in South and Central America, was introduced via Tanzania by Arab traders between 1863 and 1875 and is now one of the most important food crops. In some regions it is gaining in importance due to declining soil fertility which affects banana and plantain cultivation.

Acknowledgements

The research on interdependence was carried out under the project Strengthening National Capacities to implement the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), funded by the Directorate-General for International Cooperation, Ministry of Foreign Affairs, the Netherlands. Additional technical and financial support was provided by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). We thank Anne Vezina for her contribution to the Uganda case.

We thank Luca Pierotti for the design of the brief.
AUTHORS OF THE EIGHT COUNTRY STUDIES

Bhutan

Burkina Faso

Costa Rica

Côte d’Ivoire

Guatemala
Mendez, W., Galluzzi, G., Say, E. 2015 The importance of international PGRFA exchanges for national crop improvement: how past patterns and future needs support the implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture in Guatemala. *CCAFS Working Paper no. 154. CGIAR, Research Program on Climate Change, Agriculture and Food Security (CCAFS)*, Copenhagen, Denmark.

Nepal
Joshi, B.K., Bhatta, M.R., Ghimire, K.H. and Chaudhary, P. 2016 *Chapter I: Food and forage crop genetic resources.*

Joshi, B.K., Bhatta, M. R., Ghimire, K.H., Chaudary, P. and Singh, D. 2016 *Chapter II: Mapping and measuring the flow of interdependence of plant genetic resources.*


Rwanda

Uganda