Chapter IV : Interdependence on plant genetic resources in light of climate change

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Key messages

- Farmers' interdependence on plant genetic resources, both within Nepal and beyond, has played a pivotal role in the development of agriculture. No country in the world is self-sufficient in genetic resources.
- Climate change is further increasing this interdependence because of the need for countries to adapt by accessing new sources of biodiversity. Little is known, yet, about what shape or course interdependence will take in light of climate change adaptation in the future.
- Effects of climate change on crop yield are evident in Nepal and have stimulated efforts to identify"novel" germplasm with better adaptive capacities.
- The Climate Analogues tool can identify geographic areas with similar climate conditions (i.e., analogous sites) in current, past, and future years, leading to the possibility of finding and exchanging suitably adapted germplasm.
- Using the Climate Analogues tool, we identified current and future analogous sites within and outside Nepal, suggesting that genetic material could be exchanged with these sites. This could be done by using the ITPGRFA's multilateral system.
- Rigorous field-testing of genetic material from analogous sites will help validate the utility of the Climate Analogues tool.

For generations, farmers have been relying on each other to conserve, use, and improve plant genetic resources (PGRs) and associated knowledge and skills to ensure on-farm diversity as a strategy to secure livelihoods (FAO 2011). In addition to the unconscious actions of farmers, scientists have been making deliberate efforts to create diversity and develop biotic and abiotic stress-resistant, high-yielding varieties by manipulating genetic materials from around the world (Zeven and De Wet 1982, Ramirez-Villegas et al. 2013). No country in the world is self-sufficient in PGRs in terms of meeting domestic needs and international market demand (IPGRI 1996, Boring 2000).

Interdependence on PGRs at all levels, from local to global scales, is increasing and becoming more complex as a result of globalization and easier means of transportation. For example, some south and central African countries rely on external sources for over 80% of the germplasm they use (Palacios 1998, Ramirez-Villegas et al. 2013). Similarly, forage grasses originating in sub-Saharan Africa cover about 90% of all land under forage grasses worldwide (Boonman 1993); alfalfa (*Medicago sativa*), a forage legume species, alone covers 79 million ha of land (Putnam et al. 2007). A mega biodiversity centre in northwest India holds more than 14% of the world's cultivated plants (Brush 2013). A wheat variety, Attila, developed by breeding diverse ancestors, is cultivated on 20 million ha worldwide. In India alone, it covers 8 million ha and produces 28 million t of wheat worth over US$66.5 billion annually (Rajaram and Braun 2008, Yadav 2010).

Over 4.6 million crop accessions are available in the public domain, and the CGIAR centres alone preserve more than 700 thousand accessions of crops and forage species collected from over 100 countries (Halewood et al. 2013). These materials have been distributed mainly (more than 90%) through public research organizations, universities, regional organizations, germplasm networks, and genebanks; about 80% of distributed material goes to developing countries and countries with economies in transition (SGRP 2011).

Climate change is one of the most pressing challenges facing the world; it has already had a profound impact on PGRs and the livelihoods of people, mainly smallholders living in marginal environments (FAO 2011). Climate change may render locally available PGRs inadequate, thus underscoring the importance of access to other PGR sources (Esquinas-Alcazar 2005, FAO 2011, Fujisaka et al. 2011). Novel strategies to conserve and use PGRs are likely required to strengthen farmers' capacities to adapt to climate change. The multilateral system (MLS) of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) could be of great help in putting these strategies into practice.

The use of "climate analogues" is one such strategy. Climate Analogues is an open-access tool developed by the program on Climate Change, Agriculture and Food Security in conjunction with the International Center for Tropical Agriculture and the Walker Institute (Ramírez-Villegas et al. 2011). Used to support adaptation to climate change in the agricultural section, its main applications are in policy and planning. The tool can be used to identify future climate conditions at a particular location, sites that currently resemble these conditions, and locations that have or will have similar climate conditions. Based on careful analyses using the tool and data from actual conditions in farmers' fields, scientists can formulate possible intervention strategies, including identification of appropriate PGRs or development of new varieties for specific locations of interest (Vernooy et al. 2015). However, efforts to address climate change remain a major challenge in developing and underdeveloped countries with large numbers of smallholder farmers.

In this chapter, we analyzed temperature and rainfall trends at two reference sites and assess the impact on crop yield using rice as an example. We also identify analogous sites, identify rice collections and material in the public domain, and assess the potential for PGR exchange between analogous sites in Nepal. Data were analyzed with the help of the Climate Analogues Tool, and maps were prepared and further refined using DIVA-Geographic Information System (DIVA-GIS). Analogous sites were identified using various climate change scenarios outlined in the *Special Report on Emission Scenarios* (Nakicenovic et al. 2000). GIS has already been used to manage wild rice in Nepal and to identify analogue sites for varietal trials (Joshi et al. 2008a, 2008b).

Methods

Site and crop selection

We selected two districts as reference sites: Begnas village in Kaski district, representing the mid-hills region and Kachorwa village in Bara district, representing the lowland terai. These sites are rich in agrobiodiversity at the species, variety, and gene levels (Sherchan et al. 1998, Rana et al. 2000). Several species are rare and localized or on the verge of extinction (Chaudhary et al. 2004, Joshi et al 2005). In 1998, an in-situ conservation project was initiated at both the villages and, since then, continuous efforts have been made to promote in-situ conservation of agrobiodiversity on farm. Some important features of the project sites are presented in **Table** 4.1.

We selected rice for this study as it is the most important staple crop grown by a large number of farmers in many parts of Nepal. Farmers of both Kachorwa and Begnas grow aromatic fine rice varieties, namely Basmati and Jethobudho. There is potential for expansion of these varieties in analogue sites across the world, in particular given their economic value.

Table 4.1. Features of the two study sites

Characteristic	Begnas, Kaski	Kachorwa, Bara
Altitude (m above sea level)	668–1206	80–90
Coordinates	28°11'N, 84°09'E	26°54'N, 85°10'E
Total area (ha)*	2450	840
No. households†	596	1614
Dominant ethnic group†	Brahman, Chhetri, and Gurung	Yadav, Kanu, and Muslim
Ecological conditions	Sub-tropical to sub-temperate	Sub-tropical
Major crops, 2014	Rice, finger millet, maize	Rice, wheat, lentils, mustard
Number of rice varieties, 2014	48	99
Overall development index†	6	55

Sources: * Google Earth; † Central Bureau of Statistics (2012).

Weather and crop data

Weather data for Kachorwa and Begnas were obtained from the closest meteorological stations at Simara and Pokhara airports for the period 1971–2011. Crop yield and area data at the district level were obtained from the Ministry of Agricultural Development for the period 1991–2011. A trend analysis of maximum and minimum temperature and annual total rainfall, as well as coverage and productivity of rice was carried out to observe changes over that period. Correlation analysis between crop yield and selected climate parameters was also done for 1991–2011 to understand the impact of climate change.

Scenario analysis

We used the online Climate Analogues Tool (http://www.ccafs-analogues.org/tool/) to assess current and future climate conditions and identify sites analogous to the reference sites (**Table** 4.1). We used DIVA-GIS software (http://www.diva-gis.org) to refine the maps produced using Climate Analogues. We identified seven possible scenarios relating analogue and reference sites (**Table** 4.2).

Table 4.2. Possible scenarios for the relation between analogue and reference sites

Possible relationship	Rationale
Current situation in location X = current situation in location Y	Potential exchange of PGRs between the two locations at present time
Current situation in location X = past situation in location Y (e.g., 30 years ago)	Crops and varieties grown in location Y 30 years ago could now be introduced at location X
Current situation in location X = future situation in location Y (e.g., 30 years from now)	Crops and varieties grown in location X now could become suitable for location Y in 30 years
Future situation (e.g., in 30 years) in location X = current situation in location Y	Crops and varieties grown in location Y now could become suitable for location X in 30 years
Past situation (e.g., 30 years ago) in location X = current situation in location Y	Crops and varieties grown in location X 30 years ago could now be introduced at location Y
Past situation in location X = past situation in location Y	Crops grown in location X were likely similar to crops grown in location Y in the past
Future situation in location X = future situation in location Y	In the future, crops grown in locations X and Y could be exchanged

Of these, we analyzed three types of relationship: current situation at location X = current situation at location Y, current X = past Y, and current X = future Y. The current/current scenario allowed us to examine the relation between the baseline situation at the reference and analogue sites. Current/past and current/future comparisons allowed us to look at three scenarios based on emissions scenarios described in the IPCC's *Special Report on Emissions Scenarios* (Nakicenovic et al. 2000) and embedded in the Climate Analogues tool. The tool allows users to choose the most appropriate scenario based on specific research questions. The pertinent emissions scenarios are briefly described in **Table** 4.3.

Table 4.3. Description of emissions scenarios used for the analysis

Scenario	Description
A1B	The A1 scenario is based on the lowest population. It assumes low fertility and low mortality with a global population that peaks in mid-century (at 8.7 billion) and declines thereafter (toward 7 billion by 2100). It describes a future world of rapid economic growth and introduction of new and more efficient technologies. The A1 scenario has three sub-scenarios: fossil fuel intensive (A1FI), non-fossil energy sources (A1T), and a balance across all sources (A1B).
A2	The A2 scenario is based on the largest population (15 billion by 2100). It assumes a slow decline in fertility for most regions and stabilization at replacement levels. It falls below the long-term United Nations 1998 projection of 18 billion and describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities.
B1	The B1 scenario describes a convergent world with the same global population growth as in A1, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

Source: Adapted from Nakicenovic et al. 2000.

The matching sites were grouped into four categories based on the likelihood of matching: 0.75–1 probability (highly matching), 0.5–0.75 (moderately matching), 0.25–0.5 (less likely to match), and 0–0.25 (unlikely to match).

Selection of criteria in Climate Analogues

Using Climate Analogues, we chose monthly mean temperature and monthly precipitation under "Climatic and bioclimatic variables," as these are key factors affecting rice yield during the growing period. Temperature and precipitation were given the weights 0.4 and 0.6, respectively, as precipitation is slightly more important than temperature, as the selected site is predominantly rain fed. We used the model "Ensemble" to decrease uncertainty. For the rice-growing period, June to November was considered. For "rotation," we chose "both" as there is a high variation in both temperature and precipitation during the rice-growing season. **Table** 4.4 summarizes the selection criteria used.

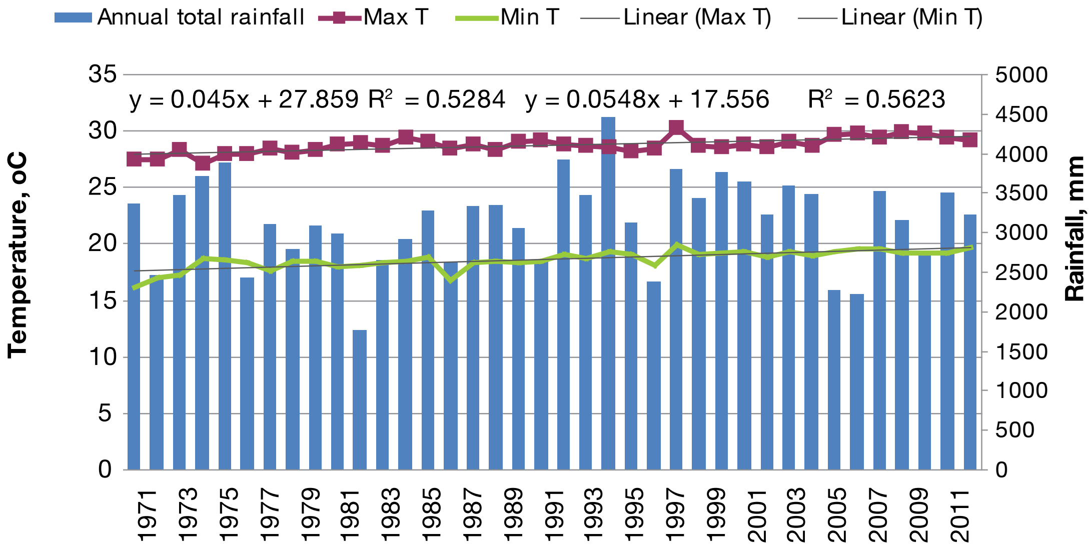
Table 4.4. Options chosen for use in the Climate Analogues tool

Time frame	Direction (comparison between)	Model	Scenario
Current–current	None (1960–1990)	Current	Baseline
Current–future	Forward (1960–1990 vs 2020–2049)	Current–ensemble	A1B, A2
Future–current	Backward (2020–2049 vs 1960–1990)	Ensemble–current	A1B, A2

Climate variability over time

A trend analysis of temperature and rainfall shows variation over time, especially in total annual rainfall, at both the study sites. Both maximum and minimum temperatures have increased over time at both the sites, more so at Begnas (Kaski district; minimum temperature has increased 0.05°C/year and maximum 0.04°C/year) as its altitude is higher than Kachorwa's (Bara district; minimum temperature increase 0.03°C/year; maximum 0.009°C/year) (**Figure** 4.1). This is consistent with previous findings showing that higher latitude and altitude regions are facing a more rapid temperature rise than lower ones (Shrestha et al. 1999, Shrestha and Devkota 2010). In both regions, the range between minimum and maximum temperatures is shrinking over time, as minimum temperature is increasing faster than maximum temperature. This is also consistent with previous findings (Houghton et al. 2001, Upadhya and Grover 2012, Mandala 2012, Krishna 2014).

Annual rainfall has fluctuated greatly over time at both Begnas and Kachorwa, making it harder to predict, unlike in the past when people were able to plan their agricultural activities based on more stable patterns. In Begnas, the least amount of rain fell in 1981 (2469 mm); Kachorwa received the least rain (893 mm) in 1972. In contrast, the years of greatest rainfall in Begnas and Kachorwa were 1995 (5102 mm) and 2007 (2380 mm), respectively (**Figure** 4.1).



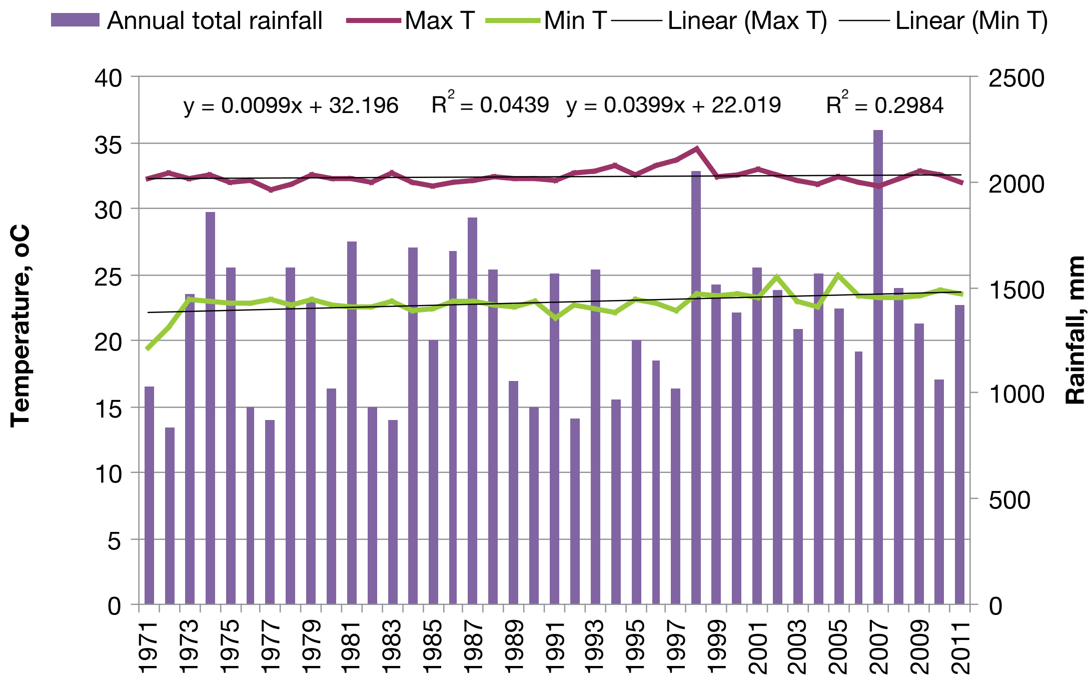
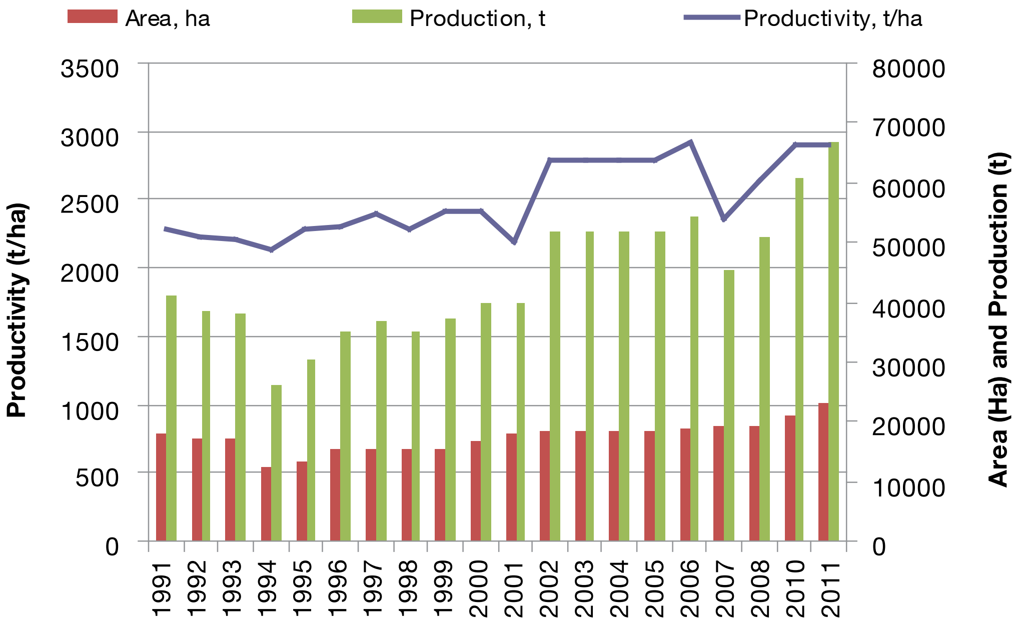


Figure 4.1. Climate patterns during the rice-growing season in Kaski (top) and Bara (bottom) districts based on data obtained from meteorological stations.

Trends in rice area, production, and productivity

At both sites, the area under rice has remained more or less constant, yet production and productivity have increased, mainly after 1996 (**Figure** 4.2). In 2007, production and productivity at both the sites decreased, which coincides with excessive rainfall in Kachorwa that year.



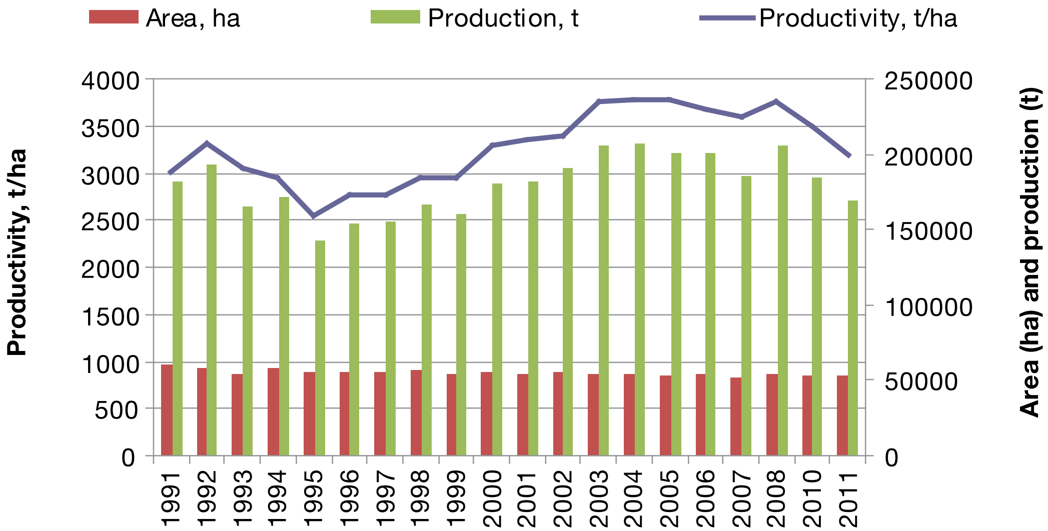


Figure 4.2. Rice production trends over years in Kaski (top) and Bara (bottom) districts.

Correlation between climate and crop yield

The data show a highly positive correlation between production and productivity; however, for other parameters, results are mixed (**Table** 4.5). For instance, in Kaski district the area planted with rice is positively correlated with productivity, whereas in Bara district the correlation is negative. Production is also positively correlated with area to a significant degree in Kaski, but negatively correlated, although not at a significant level, in Bara.

Table 4.5. Correlation between rice production and climatic parameters for Begnas (Kaski) and Kachorwa (Bara), 1991–2011

	Area	Production	Productivity	Max. temp.	Min. temp.
Begnas, Kaski					
Production	0.934**				
Productivity	0.703**	0.907**			
Max. temp.	0.383	0.363	0.286		
Min. temp.	0.3252	0.348	0.306	0.536**	
Seasonal rainfall	-0.241	-0.297	-0.342	-0.216	0.330
Kachorwa, Bara					
Production	-0.159				
Productivity	-0.456*	0.951**			
Max. temp.	0.362	-0.531**	-0.593**		
Min. temp.	-0.546**	0.249	0.393*	-0.093	
Seasonal rainfall	-0.315	0.087	0.181	-0.071	0.176

* and ** Significant at 5% and 1%, respectively.

Past, present, and future analogous sites

Our analysis clearly showed a number of sites that are analogous to Begnas and Kachorwa (**Tables** 4.6 and 4.7 and **Figures** 4.3 and 4.4). The analysis revealed that some of the districts are in common, but locations differ slightly for current, future, and past scenarios and some districts in each category do not match each other. It was also obvious that most of the future analogous sites are north of the reference sites, which indicates that rising temperatures are making sites more similar to previously warmer locations in lower altitudes in the southern region. The northern regions are generally colder and at higher elevations than the southern regions.

Table 4.6. Districts of Nepal that may be analogues of Begnas (reference site) currently, in the future, and in the past

Probability of matching	Current analogue sites	Future analogue sites (forward selection)	Past analogue sites (backward selection)
Highly likely (0.75–1)	Dhading, Gorkha, Kaski, Kavrepalchok, Nuwakot, Sankhuwasawa, Sindhuli, Sindhupalchok, Southern, Tanahun, Taplejung **(11)**	Dhading, Dolkha, Gorkha, Kaski, Kavrepalchowk, Khotang, Lamjung, Makwanpur, Myagdi, Nuwakot, Ramechhap, Sankhuwasabha, Sindhupalchowk, Solukhambu, Syangja, Tanahun **(16)**	Bhojpur, Dhading, Dhankutta, Gorkha, Ilam, Khotang, Morang, Nuwakot, Solukhumbu, Tanahun, Terathum **(11)**
Moderately likely (0.5–0.75)	Syangja, Ilam, Dhankuta, Bhojpur, Sankhuwasabha, northern part of Morang, Bara, Parsa, Rautahat, Sarlahi, Mahotari, Dhanusa, Siraha, north and east Chitwan, mid-western Dang Some Parts of Baitadi, Dadeldhura, Kailali, Doti, Achham, Surkhet, Dailekh, and Salyan Central Kaski, eastern Parbat **(25)**	Parbat, Syangja, Palpa, Dhading, Gulmi, Terathum, Panchthar, Dhankuta, Bhojpur, and Khotang Central and southern Kaski, Lamjung, Gorkha, SIndhupalchowk, Dolkha, Sankhuwasabha, and Taplejung Northern Makwanpur, Ilam, Sindhuli, and Udapur Parts of Baitadi, Dadeldhura, Kailali, Doti, Achham, Surkhet, Dailekh, and Salyan **(29)**	Bardiya, Banke, Kapilvastu, Rupandeshi, Nawalparasi, Tanahun, Chitwan, Parsa, Bara, Rautahat, Sarlahi, Mahotari, Dhanusa, Siraha, Sunsari, Morang, Jhapa, Ilam, Dhading, Dolkha, Sindhupalchowk, and Nuwakot Some Southern parts of Kaski, Lamjung, Gorkha, and Terathum Parts of Baitadi, Darchula, Dadeldhura, Kanchanpur, Kailali, Doti, and others **(32)**

Probability of matching	Current analogue sites	Future analogue sites (forward selection)	Past analogue sites (backward selection)
Less likely (0.25–0.5)	Almost all districts of Nepal	Almost all districts of Nepal **(75)**	Almost all districts of Nepal except Bara, Parsa, Rautahat, Sarlahi, Mohattari, Dhanusa, Siraha, Saptari, Sunsari, Jhapa **(65)**
Unlikely (0–0.25)	No districts	No districts	No districts

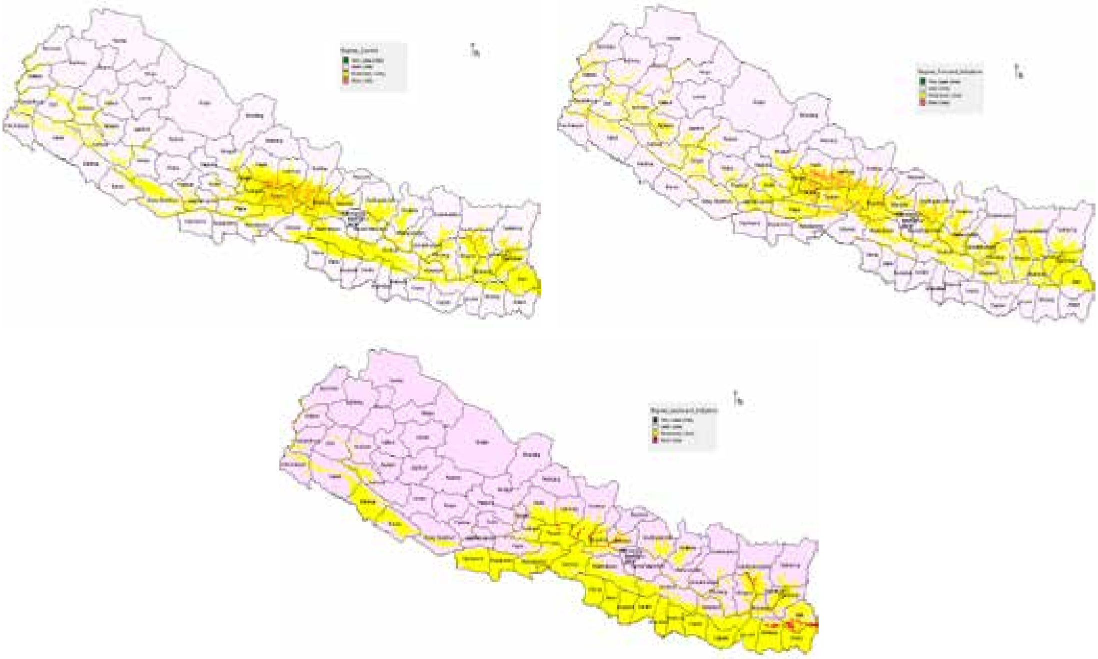


Figure 4.3. Sites in Nepal that may be analogous to Begnas currently (top left), in the future (top right), and in the past (bottom).

Table 4.7. Districts of Nepal that may be analogues of Kachorwa (reference site) currently, in the future, and in the past

Probability of matching	Current analogue sites	Future analogue sites (forward selection)	Past analogue sites (backward selection)
Highly likely (0.75–1)	Kapilvastu, Rupandeshi, Nawalparasi, Chitwan, Parsa, Bara, Rautahat, Sarlahi, Mahottari, Dhanusa, Siraha, Saptari, Sunsari, southeastern Udaypur, southwestern Morang, northwestern Banke **(16)**	North and south Palpa, northern Parsa, Bara, Mahotari, and Sarlahi Southern Chitwan, Makwanpur, Sindhuli, Udaypur, Pyuthan, Dang, Arghakachi, Syangja, Dadeldhura, and Gulmi Parts of Baitadi, Achham, Doti, Salyan, Saptari, Banke, and Kanchanpur **(22)**	No districts

Probability of matching	Current analogue sites	Future analogue sites (forward selection)	Past analogue sites (backward selection)
Moderately likely (0.5–0.75)	Kanchanpur, Kailali, Bardiya, Banke, Dang, Kapilvastu, Rupendehi, Morang, Jhapa, Sindhuli, Dhankutta, Tanahun, southern Makwanpur, Ilam and Khotang, eastern Bhojpur, western Surkhey, and Dadeldhura Parts of Dhading, Nuwakot, Kavrepalanchowk, Ramechap, and Okhaldhunga **(23)**		Morang, Jhapa, Sunsari, Saptari, Siraha, Dhanusa, Mahotari, Sarlahi, Rautahat, Bara, Parsa, Rupendehi, Kapilvastu, Bardiya, Banke, Kanchanpur, and Chitwan Southern parts of Kailali, Makwanpur, Sindhuli, Udaypur, and Ilam Parts of Surkhet, Dadeldhura, Salyan, Pyuthan, Palpa, Tanahun, Dhading, Kavrepalanchowk, Okhaldhunga, and Khotang **(33)**
Less likely (0.25–0.5)	Almost all districts of Nepal except Bara, Parsa, Rautahat, Sarlahi, Mohattari, Dhanusa, Siraha, Saptari, Sunsari, and Jhapa **(66)**		All except Bara, Parsa, Rautahat, Sarlahi, Mohattari, Dhanusa, Siraha, Saptari, Sunsari, Morang, Rupendehi, and Jhapa **(62)**
Unlikely (0–0.25)	No districts	No districts	Some parts of Mugu **(1)**

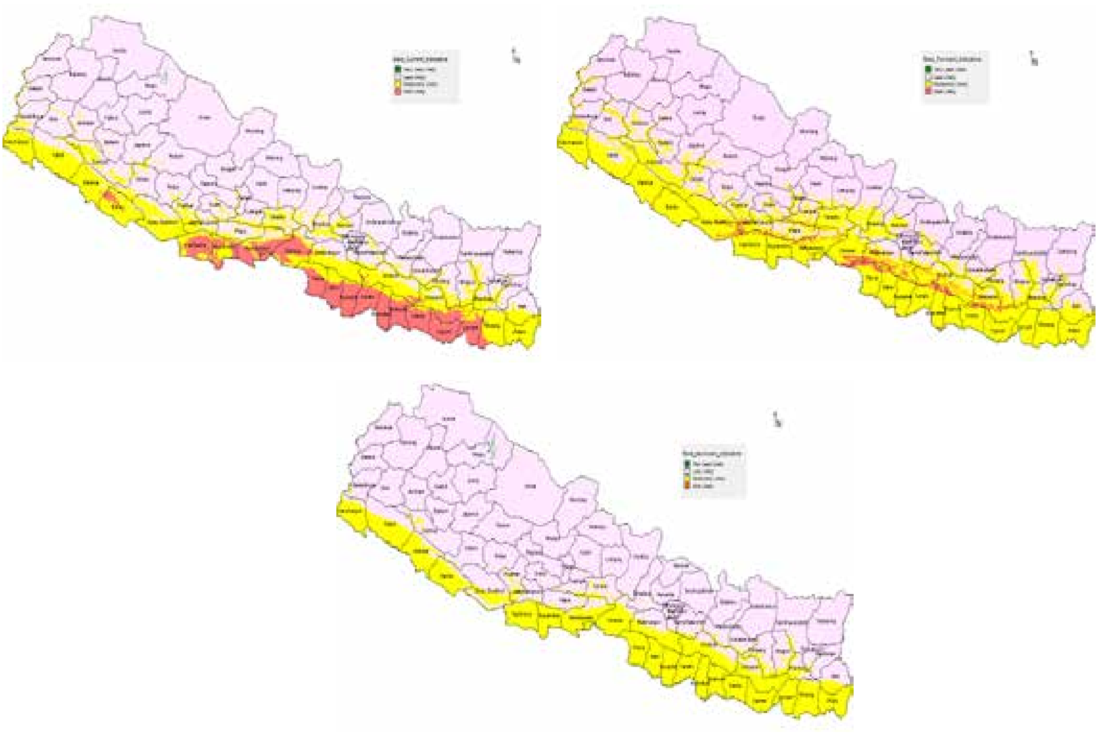


Figure 4.4. Sites in Nepal that may be analogous to Kachorwa currently (top left), in the future (top right), and in the past (bottom).

Analogue sites outside Nepal

We found a number of locations around the world that match at present, will match in future, and matched in the past the current conditions at the reference sites. Highly matching analogous sites for Begnas are found in some parts of China, and for Kachorwa such sites are found in Bihar, Jharkhand, Madhya Pradesh, and Uttar Pradesh, India (data not presented here). Current analogous sites for Begnas and Kachorwa in Asia are listed in **Table** 4.8. Current analogous sites for both locations are depicted in **Figure** 4.5.

Table 4.8. Locations in Asia that might be analogous to sites in Begnas and Kachorwa

Probability of matching	Analogue sites of Begnas	Analogue sites of Kachorwa
Highly likely (0.75–1)	Wucunxiang, China	Bariarpur Kuntari, Bihar, India; Tati, Jharkhand, India; Dindori, Madhya Pradesh, India and Sisotar, Uttar Pradesh, India
Moderately likely (0.5–0.75)	Gowaryo, Pakistan; Kerman and Horozygon, Iran; Hainana Sheng, China; Salavan, Laos	Shandong Sheng, China; Indus river side Pakistan; Henan Sheng, China; Vietnam; Pichaguntrahalli, Karnataka, India; Gorja, Pakistan; Kerman, Iran; Baldwyn, Saudi Arabia
Less likely (0.25–0.5)	Most of the Asian region	Most parts of Asia
Unlikely (0–0.25)	Zhejiang, China; Ayni, Tajikistan; Victoria, Sri-Lanka; Shirmine, Japan	Gifu-shi, Gifu-ken, Japan; Meghalaya Kynshi, India; Changsha Shi, Changsha Xian, China; Hasalaka Road side, Ulpathagama, Sri Lanka; Chatkal, Kyrgyzstan; and many others

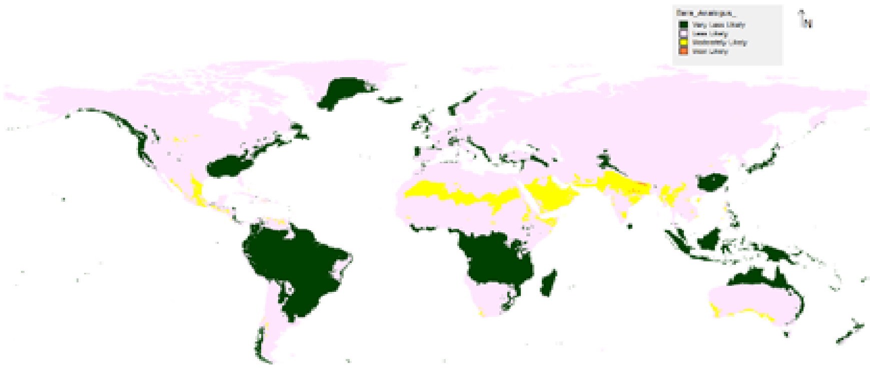


Figure 4.5. Locations throughout the world that may be analogous to Begnas (top) and Kachorwa (bottom).

Wild rice collection sites and their analogues in Nepal

Wild rice collection sites are shown in **Figure** 4.6 and current analogous sites for the species *Oryza rufipogan* are shown in **Figure** 4.7 (a, b). The wild rice habitats are mostly found in the terai and inner terai region with few exceptions for the mid-hill regions of the country. For *O. rufipogan*, the current analogous sites are near the southern borders, while the future analogue sites are likely to move northward.

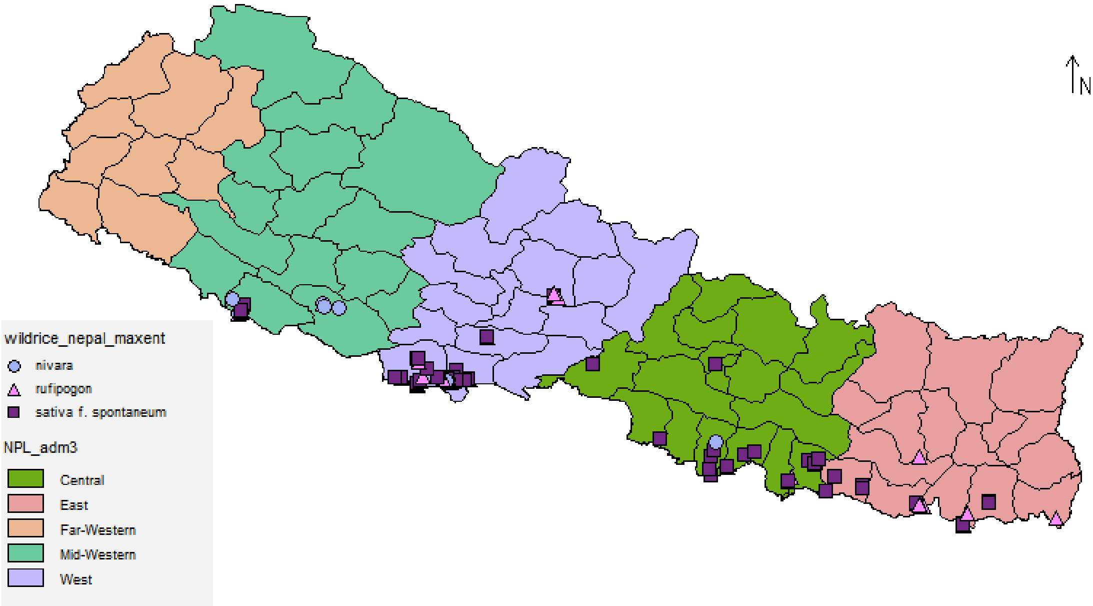


Figure 4.6. Nepal map showing wild rice collection sites.

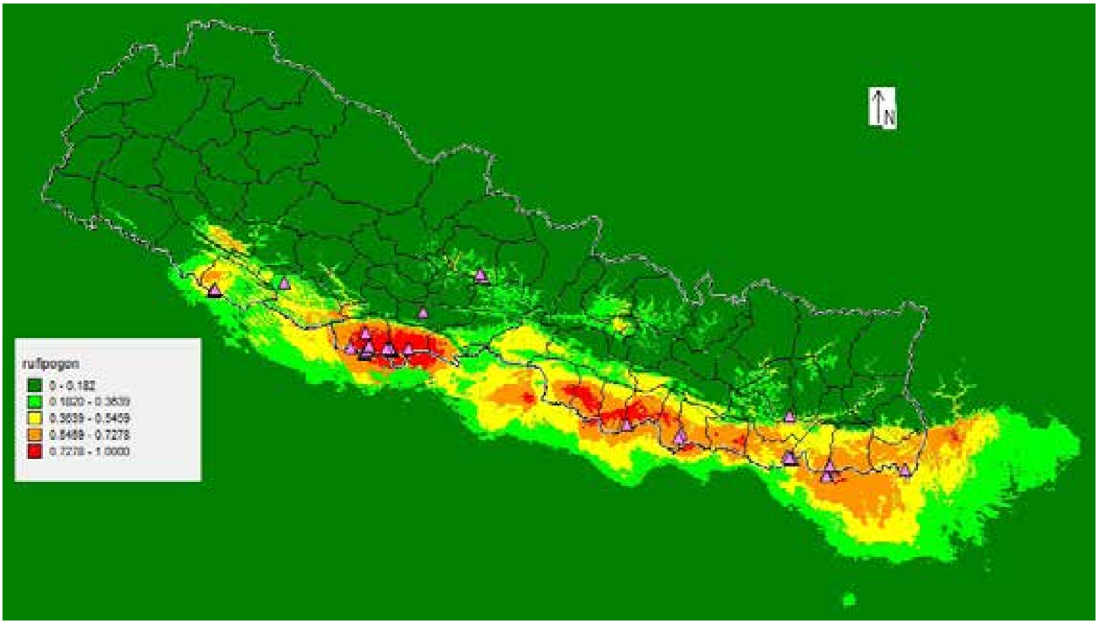


Figure 4.7(a). Climate analogue sites for *Oryza rufipogan* at present in Nepal.

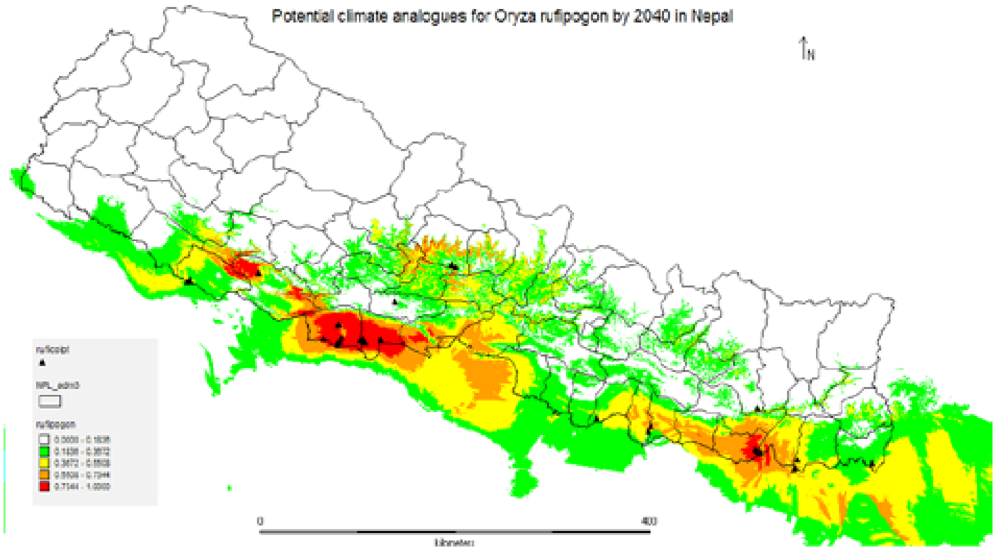


Figure 4.7 (b). Climate analogue sites for *Oryza rufipogan* at future 2040 in Nepal.

Collection sites and analogues for PGRs available in the public domain

The national genebank (the National Agriculture Genetic Resources Centre), an agency in the public domain, preserves more than 11000 accessions of various crop species (1141 species of rice alone) that were once grown or are currently grown in the country. Similarly, 2839 accessions from various parts of the country have already been added to the global gene pool, mainly via the International Rice Research Institute, other CGIAR centres, and the United States Agency for International Development (for details, see chapter 1). Some of the accessions found in these public domain collections serve as backup duplicates of material preserved in community seed banks managed by farmers and are grown by farmers on farm.

A total of 100 rice accessions from the Kachorwa site can be found in Genesys and 15 in the National Agriculture Genetic Resources Centre.

Key findings and the way forward

Our findings vividly reveal that climate change is an inevitable problem facing Nepal and will have both positive and negative implications for crop production and productivity — at varied scales in different locations and over different timespans. When existing crop diversity is inadequate to survive changing conditions, new varieties will be required to adapt to those changes. This will increase interdependence on PGRs among regions and countries.

Going forward, the first step is to identify possible matching sites between which genetic material could be exchanged for potential adaptation to new environments. It is also important to assess crop diversity at the matching sites, and then examine what crops and varieties could be exchanged and tested between the sites.

The analysis using the Climate Analogues tool suggests that current, future, and past analogue sites exist, both within the country and beyond, that could exchange genetic material. Many regions are similar at present, while many others will become similar in future. Although we can promote material exchange among current analogous sites now, the future will also open up the possibility of exchange between different locations. Several of the matching districts were recently affected by earthquakes, suggesting that materials could be transferred from less- to more-affected regions to supply farmers who lost seeds during that crisis. Among countries, genetic materials could be exchanged between similar regions, using the Standard Material Transfer Agreement through the ITPGRFA's MLS, if analogue regions are in signatory countries.

Accessions preserved in genebanks will be useful now and in the future as climate alters, as they can be transferred to various locations depending on need. To be useful in the future, genebank material must be carefully preserved. However, in this process, policies on farmers' rights and access and benefit sharing mechanisms must be developed and put into practice to avoid conflicts over the roles of custodian farmers.

Our study shows that wild rice sites exist and that there are suitable habitats for wild rice at various locations; new sites may also become suitable for regeneration in the future. Some analogue sites may still have wild rice, but they remain unexplored. Analogue sites for material in the public domain, including holdings of the national genebank, could be used to regenerate ex-situ material periodically, so that this material can co-evolve under local climatic conditions to some extent and adapt to changing biophysical conditions.

In the future, we intend to identify more precisely which analogue sites could be used to develop location-specific strategies to adapt to climate change and build the resilience of farmers. Field-testing of novel genetic material will be the ultimate test of the utility of the Climate Analogues tool. Before any new form of exchange of genetic materials can be established, it is important to examine agricultural diversity (crops and crop varieties grown on-farm) and other basic characteristics of the reference and analogous sites and assess the potential for material exchange among them.

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