Journal of Agriculture and Natural Resources (2020) 3(2): 9-20
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

Research Article

Germplasm rescue and rebuilding local seed systems in red zone areas

Bal Krishna Joshi[1*], Devendra Gauchan[2], Shreejana Sapkota[1], Kritesh Poudyal[1], Krishna Hari Ghimire[1] and Durga Man Singh Dongol[3]

[1]National Agriculture Genetic Resource Center (NAGRC), NARC, Khumaltar, Nepal
[2]Alliance of Bioversity International and CIAT, Kathmandu, Nepal; d.gauchan@cgiar.org
[3]Food Research Division, NARC, Khumaltar, Lalitpur, Nepal; durgadongol@yahoo.com

* Correspondence: joshibalak@yahoo.com
ORCID: http://orcid.org/0000-0002-7848-5824
Received: August 07, 2020; Accepted: October 03, 2020; Published: October 30, 2020

ABSTRACT
Native agrobiodiversity become endangered and even lost due to natural disasters in red zone area such as earthquake that hit Nepal on April and May 2015. Endangered agricultural genetic resources should be rescued and revival of disrupted local seed system was essential for sustainable and productive agriculture in earthquake affected areas. The objectives of this paper are to document methods employed to rescue germplasm and rebuild local seed systems in earthquake affected areas to restore lost crop diversity and strengthen local seed systems. Among 14 severely hit districts by April 2015 earthquake in Nepal, 10 districts were selected for germplasm rescue and rebuilding local seed system. We surveyed households and sensitized relevant stakeholders. Earthquake affected areas were declared as red zones and status of crop landraces were assessed through survey, five cell analysis and focus group discussion. Three germplasm rescue techniques, namely direct rescue, diversity fair and indirect rescue were applied. Local seed systems were rebuilt through diversity fair, diversity block, seed exchange, repatriation and diversity kits. Collected accessions were characterized, multiplied and conserved in National Genebank and community seed banks. About 5-10% of total local crop diversity (based on the landraces) were lost due to earthquake in these districts. A total of 921 accessions of 61 crops along with 284 rare and endangered crop landraces were collected and rescued from 35 VDCs of 10 severely earthquake affected districts. Climate analogue sites and climate smart germplasm were identified for some of earthquake affected areas, and five landraces of four crops were repatriated. Participatory seed exchange, diversity fairs and 200 diversity kits (containing 3 to 5 varieties) were employed to revive the local seed systems. Farmers' preferred landraces were conserved in Community Seed Bank in Lamjung and Dolakha and all collections were conserved in Naional Genebank, Khumaltar, Nepal. The study concludes that multiple approaches and tools are necessary for germplasm rescue and rebuilding local seed systems from red zone area

Keywords: Agrobiodiversity, analog sites, earthquake, red listing, repatriation

Correct citation: Joshi, B.K., Gauchan, D., Sapkota, S., Poudyal, K., Ghimire, K.H., & Durga Dongol, D.M.S. (2020). Germplasm rescue and rebuilding local seed systems in red zone areas. *Journal of Agriculture and Natural Resources*, *3*(2), 9-20, DOI: https://doi.org/10.3126/janr.v3i2.32294

Journal of Agriculture and Natural Resources (2020) 3(2): 9-20
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

INTRODUCTION

Agrobiodiversity always remains prime importance for human life and maintaining healthy environment. In Nepal, there are total 24,300 species and among them 28% are agriculturally valued (Joshi et al., 2020a). Agrobiodiversity genetic resources are being evolved, maintained and produced in wide range of altitudes ranging from 60 to 5000 meter above sea level (Joshi et al., 2017a; Upadhyay & Joshi, 2003). After the advancement of science including agriculture, many agricultural genetic resources (AGRs) were lost and many are endangered (FAO, 1999; Chaudhary et al., 2020; Upadhyay & Joshi, 2003; Joshi et al., 2020a; Joshi et al., 2005). Farming lands become risky in terms of losing native AGRs. Both natural disasters and human activities made agrobiodiversity endangered in particular areas called red zones (Joshi, 2019; Joshi & Gauchan, 2017). The massive earthquake of 7.6 Richter scale in April 2015 converted farming lands of more than 30 districts of Nepal into red zones. There were death tolls of 9,000, with additional 23,000 injured and more than 785,000 homes damaged or destroyed, and about 2.8 million people displaced due to this mega earthquake (NPC, 2015). Stored food grains and seeds amounting to more than US$80 million were lost. The earthquake triggered loss of seeds and crop diversity due to destruction of storage structures, burial of stored seeds and damage of agricultural land (Gauchan et al., 2017). About 70% of farm households lost more than 60% of their seed stock and crop genetic resources stored in their household stores (FAO, 2015; NPC, 2015).

Many organizations and Government of Nepal took immediate action to rescue the human lives in earthquake affected areas. But the most important resources for human survival, i.e. agricultural genetic resources were not rescued though these resources were at the risk of being lost. Local seed systems were completely disrupted. Vulnerability of local seed systems was further accelerated through introduced, untested seeds in the name of immediate relief packages. Germplasm rescue and revival of local seed systems were therefore urgently needed in earthquake affected districts for long term secured agricultural farming. Majority of farming households in Nepal depends on local seed systems (Gauchan & Shrestha, 2020; Joshi *et al.*, 2020b) and if disrupted, food production and continuity on agriculture will be hampered. More than 90% farmers in the earthquake affected areas depended on the use of self-saved and locally exchanged seeds of native crop landraces.

Germplasm rescue has been in place since 2015 in Nepal (Joshi, 2017) and have rescued more than 1000 accessions of endangered, rare and vulnerable landraces from across the country (Joshi & Gauchan, 2017). Red zoning and red listing have become simple practical tools to facilitate the germplasm rescue mission in the country (Joshi & Gauchan, 2017; Joshi, 2019; Joshi *et al.,* 2017b; Joshi *et al.,* 2004). To understanding the red zones for agrobiodiversity and destruction of local seed supply system in earthquake affected districts, a germplasm rescue and rebuilding local seed system project were implemented in earthquake affected areas with the objectives to restore lost crop diversity and local seed systems; to rescue germplasm and conserve them in National Genebank and local community seed banks; to characterize, evaluate and multiply farmer preferred and adapted rescued seeds and repatriate (distribute back), and to strengthen capacity of stakeholders in rescue mission and rebuilding sustainable local seed system. This paper explains the diverse methodologies and approaches adapted for germplasm rescue and rebuilding local seed systems.

Journal of Agriculture and Natural Resources (2020) 3(2): 9-20
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

MATERIALS AND METHODS

Site selection, survey, sensitization

Fourteen districts were severely hit and 17 districts were moderately hit by 2015 earthquake in Nepal (NPC, 2015). Among them 10 severely hit districts were selected based on accessibility, crop diversity and extent of damage for germplasm rescue and rebuilding native seed systems (Gauchan *et al.*, 2017). These 10 districts were Lamjung, Dolakha, Kavre, Sindhupalchok, Gorkha, Dhading, Makawanpur, Rasuwa, Nuwakot and Ramechhap. Rescue team and other relevant stakeholders were oriented and trained. Detail action plans were developed for stakeholder sensitization, field visits, germplasm rescue, rebuilding local seed systems, etc. We conducted key information survey and stakeholder consultation meetings to identify affected locations falling into red zone, communities, crops and landraces in each district. Focus group discussion, participatory exploration, household survey and field observations were organized for gathering information, sharing germplasm and collecting crop diversity from the red zone areas.

Declaring red zone for agrobiodiversity

During the consultation meeting, earthquake affected areas were defined as red zones i.e. areas with the greater chance of losing majority of the native agricultural genetic resources within short period time or less than five years (Joshi & Gauchan, 2017). After consultation with local communities. districts agricultural development offices and other key district stakeholders, we identified most affected village development committees (VDCs) which are considered as red zone areas for the field survey and rescue collections. These include 35 VDCs of 10 districts covering 2-4 VDCs from each district. We requested all stakeholders to work on this mission, considering these areas as red zones.

Determination of conservation status of germplasm

Conservation status (also called red listing) of germplasm declares the current chance of eroding a particular genotype from the fields. It identifies the requiring immediate action to rescue and use along with to design periodic base conservation action plan for each genotype. We used three approaches for red listing the crop diversity. We surveyed household as well as field to know the status of different landraces in a particular area. Secondly, analysis of distribution and population size of landraces was done which is commonly called four-cell analysis (Sthapit *et al.,* 2010). We developed five-cells rather than four-cell for landraces based on area coverage and number of households growing landrace (Figure 1) (Joshi and Gauchan 2017). In similar way, landraces were categorized into four groups based on distribution and frequency of particular trait (Joshi & Gauchan, 2017). We organized focus group discussion for second and third approaches.

Journal of Agriculture and Natural Resources (2020) 3(2): 9-20
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

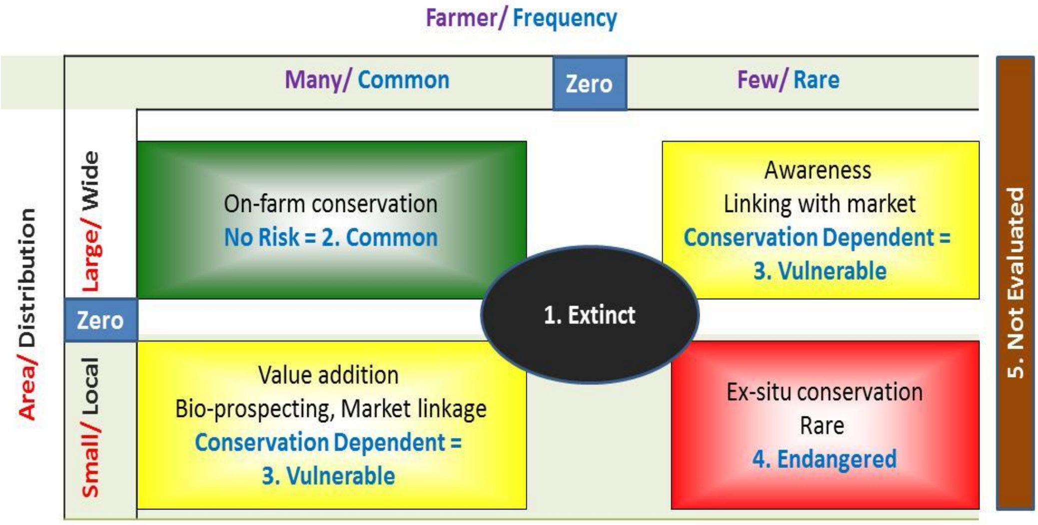

Figure 1. Criteria for grouping landraces based on distribution and populations size

Germplasm rescue mission

Rescue team visited many households, fields, collapsed buildings and interacted with farmers and officials for exploration and collections of endangered and non-endangered crop landraces in red zone areas of 35 VDCs of 10 most earthquake affected districts. In some cases, seeds were collected from remnant plants directly from the field. Team also harvested seeds from the standing crops grown within collapse buildings (some seeds of some crops were germinated within collapse buildings). Planting materials were also searched in collapse building and seeds were collected through digging out the buildings for getting seeds with the help of farmers. Seeds were also directly collected from farmers after convincing them for some crop landraces and providing them diversity kits in exchange. Diversity kit is the pack of seeds of few landraces of different crops that includes improved varieties, landraces, elite lines, etc. During household visit, farmers were also enquired regarding where-abouts of lost landraces nearby. Then team visited these sites for seeds collections. Passport data were also filled in during seeds collections.

We used three germplasm rescue techniques, namely direct rescue, diversity fair and indirect rescue (Joshi & Gauchan, 2017). Under direct rescue, team visited fields and collected seeds/ planting materials both from farmer's stores and fields. Under indirect rescue, farmers and stakeholders rescued germplasm themselves and provided seeds to National Genebank. Diversity fairs (Sthapit *et al.*, 2006) were organized and seeds along with information were collected from such fairs.

Rebuilding local seed systems

For rebuilding native seed systems, we organized diversity fairs and participatory seed exchange event to accelerate and facilitate the access to seeds of different crop species. We also identified the climate analog sites along with site details for these earthquake-affected areas using geographical information system (GIS), climate analog tool (CAT) and GoogleEarth. Analog sites were also located based on focus group discussion and key informant survey. Seeds were collected from these analog sites and distributed to the farmers of earthquake areas and repatriated in some locations.

Journal of Agriculture and Natural Resources (2020) 3(2): 9-20
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

Rare, endangered and lost landraces along with farmers' preferred landraces were collected from different means and strategies for repatriation. We analyzed the collections in Genebank and collections before earthquake from these target sites were used to distribute to farmers. Elite lines, farmers' preferred landraces were further collected from Genebank, research stations, Community Seed Bank, analog sites and International Rice Research Institute (IRRI). Genesys database was used based on the analog sites of earthquake areas for choosing rice accessions from IRRI (details of generating such information is described by Chaudhary *et al.,* 2016; Joshi *et al.,* 2017c). Lost landraces were also searched by their name to other areas and sources. We also provided diversity kits to deploy diversity. These approaches are very important for reviving the local seed systems and repatriation of crop diversity.

Diversity blocks of farmers' preferred landraces were established in different districts, in community seed banks and in Khumaltar for distribution and providing farmers an option to select their choices. In addition, such blocks were used for seed multiplication and characterization.

Seed multiplication, characterization and conservation

Seeds of collected diversity (of which diversity blocks were not established) were multiplied and characterized in Khumaltar establishing seed increase blocks. The specific traits of all the collections were documented and then conserved in National Genebank and some of them were multiplied in Community Seed Banks in Jungu, Dolakha and Ghanpokhara Lamjung to facilitate their utilization and repatriation back to local communities in red zone areas. All these activities were carried out from August 2015 to December 2017.

RESULTS AND DISCUSSION

Understanding agrobiodiversity

The earthquake affected areas were found rich in all components of agrobiodiversity i.e. crops, forages, livestock, aquatic, insects and microorganism. Almost 95% of these diversities were found native for these areas and at least some traits were evolved. We only worked on crop biodiversity due to financial and manpower constraints. We found total 150 crop species in 10 earthquake affected districts and large number of landraces of these crop species. About 5-10% of total crop landraces were lost due to earthquake. An estimated 20% of crop landraces would have been lost in absence of this rescue mission. Diversity could be measured at ecosystem, species, landrace, genotype and allelic levels (Joshi *et al.,* 2020a), but we only assessed diversity at species and landrace levels from the red zone areas. Genotypic level diversity was assessed in 173 landraces. Cereals dominated in the diversity study and collections (Gauchan *et al.,* 2020) and it is common trend to favor more for cereal crops though there are various valuable and life survival related species (Joshi *et al.,* 2019; Pudasaini *et al.,* 2016).

Earthquake making landraces endangered

Discussion regarding vulnerability of different landraces due to earthquake was made among the farmers and experts. The reasons of making landraces endangered due to earthquake are, *ad hoc* distribution of planting materials (including relief materials) collected from outside

Journal of Agriculture and Natural Resources (2020) 3(2): 9-20
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

the target areas by different organizations; damage of standing crops by landslides; damage of grain and seed stores by collapse of house buildings; remaining of few amounts of plant materials which could not adequately cover the planting areas. Therefore, farmers went to other alternatives; many crops could not be harvested, and stored seeds and grains were used as food due to scarcity of the foods and farmers forced to migrate abandoning agriculture and planting materials.

In general condition, crop landraces are endangered due to distribution of modern varieties; introduction of foreign germplasm; natural and human made disasters; epidemics of diseases and insect pests; changes in land use pattern and leaving land fallow or habitat loss; changes in occupation, abandon agriculture, war or insurgency; old trees of which progeny has not been generated; rapid commercialization of agriculture; mono-genotyping; migration of farmers and land abandonment for cultivation, and over-exploitation e.g. loss of species caused by over-grazing or by uncontrolled harvesting in the wild, etc. Chaudhary *et al.*, (2020) has grouped many factors related to agrobiodiversity under natural and human made.

Germplasm rescue and diversity collections

Existing diversity at species level were assessed in 10 affected red zone districts. Landrace richness and their status (red listing) were also measured and endangered, rare and vulnerable along with lost landraces were listed, located and documented with some detail. A total of 284 rare and endangered crop landraces were rescued and conserved in National Genebank and some in community seed banks. . We rescued the 73 landraces that were endangered due to earthquake (Figure 2). A total of 921 accessions of 61 crops were collected from 35 VDCs of 10 severely earthquake affected districts. Germplasm rescue is very important for stopping genetic erosion, and therefore different approaches should be kept always ready (Joshi & Gauchan, 2017). Red zoning and red listing (Joshi, 2019) are widely applied across the country to facilitate the rescue mission. During collection, each diversity (genotype) was given equal value expecting to capture available diversity. Special attention should be given to hot spot areas of diversity and sampling techniques (Guarino *et al.*, 1995).

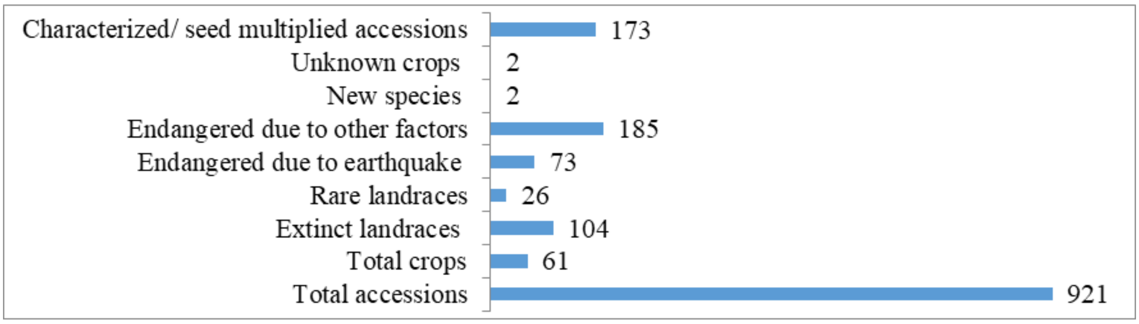

Figure 2. Number of accessions of different crop species in different categories collected from earthquake affected districts.

Analog sites, climate smart germplasm and repatriation

Collection map of Genesys data base and National Genebank were used to identify the climate smart germplasm. Climate analogue sites and climate smart germplasm were identified for some of earthquake affected areas (Figure 3). More than 100 accessions were

Journal of Agriculture and Natural Resources (2020) 3(2): 9-20
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

located as climate smart germplasm based on analog site that could be useful and importance to repatriate and to rebuild the local seed systems. Among them, five landraces of four crops were repatriated. Two types of germplasm were considered for repatriation based on the origin of that germplasm, one is from analog sites and another one is those that were collected earlier and stored in Genebank, and therefore reintroduction to their original collection sites. Analog site-based germplasm exchange is also better strategy in the context of climate change (Joshi *et al.*, 2017c). Large number of accessions was identified using this tool (Poudyal *et al.*, 2017). This also support for repatriation, which help to increase diversity as well as balancing the environment (Friis-Hansen & Kiambi, 1998; Dongol *et al.,* 2017).

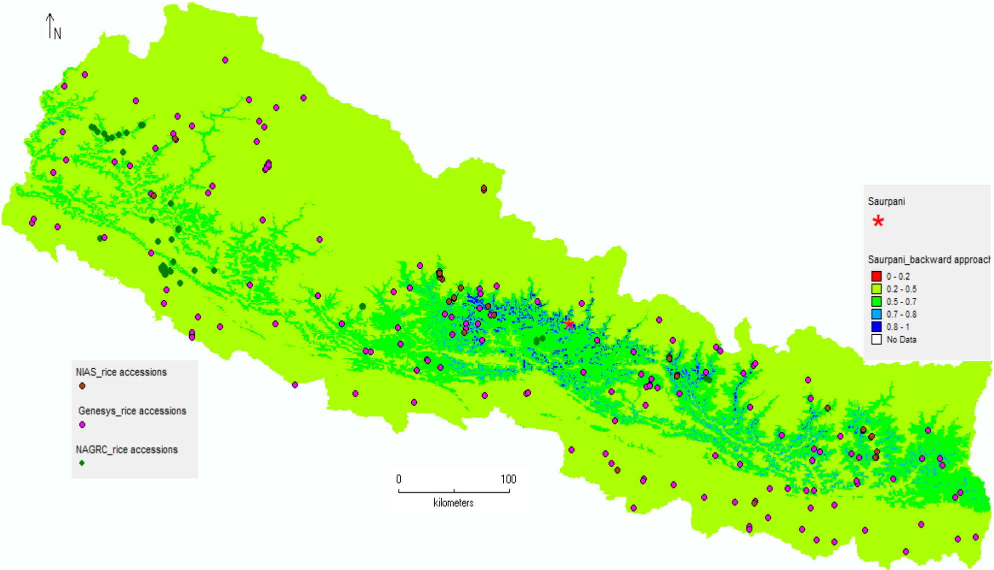

Figure 3. Climate analog sites of Saurpani VDC, Gorkha with overlayered the collection points of rice germplasm that were conserved in International Genebanks (Genesys and NIAS) and National Genebank.

We analyzed the accessions that were collected from earthquake affected areas before 2015 earthquake and conserved in National Genebank. Collection map based on these collections were developed and used for gap analysis (Ghimire *et al.*, 2017). A total of 852 accessions of 40 crops from 13 earthquake affected districts collected before 2015 were found conserved in National Genebank (Figure 4). They were from 250 to 2677 masl. These collections were found very important and useful to revive the local native seed systems in these areas. The maximum number of collections (406 accessions of 22 species) was from Dolakha district, and the minimum (11 accessions) was from Makawanpur. In these collections, the maximum number was of rice (385), followed by finger millet (218) and maize (202). The highest number of species was collected from Rasuwa.

Journal of Agriculture and Natural Resources (2020) 3(2): 9-20
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

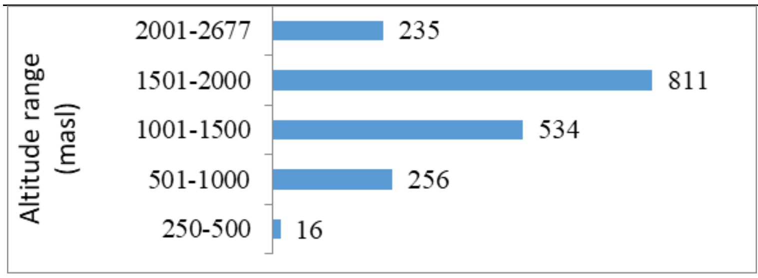

Figure 4. Total accessions of crop species collected from earthquake affected areas before 2015 mega earthquake and conserved in National Genebank, Khumaltar, Nepal.

Seed multiplication, characterization and conservation

Following the genebank standard, these collected accessions were multiplied in Khumaltar for storing in long- and medium-term storages of National Genebank. Passport data, image bank and characterization data were also maintained in database. Some farmers' preferred landraces were also multiplied in two community seed banks, one in Lamjung and another in Dolakha. These community seed banks have maintained and shared these landraces with the farmers for their own crop production and use.

Rebuilding local seed system

Local seed system was completely destroyed due to loss of native crop seeds and collapse of house and other buildings in the red zone areas. Remaining seeds even in some cases were used for food. The awareness and capacity of 22 staffs, 425 farmers and 35 extension and development workers were enhanced for establishing and strengthening local seed systems along with management of native agrobiodiversity. These areas had thousands of different landraces of many crop species growing since ancient times. Informal seed systems - dominated before the earthquake. To rebuild the seed systems, focus was given to restore the lost landraces, and provide maximum diversity. Based on farmers' information, landraces of similar types were searched in many locations e.g. nearby districts, analog sites, genebanks, research stations, neighbors and relatives. Rescued germplasms were also distributed to farmers and similar localities. Local seed system with this pool of landraces was restored through diversity fairs, diversity blocks, diversity kits, participatory seeds exchange event and repatriation. About 200 diversity kits were provided to 200 farmers to support for reviving the local seed systems. Old collections from Genebank, that were collected from earthquake affected districts were repatriated. A total of 485 farmers had brought 2058 samples of seeds to share and 503 farmers took 1249 samples of seeds from the six participatory seeds exchange events (Gautam *et al.*, 2017). Among these materials, over 90% were not notified in official list (Gauchan *et al.,* 2016). Five rescued landraces were also repatriated to other climate analog sites. Local seed systems were linked with community seed banks in Lamjung and Dolakha districts.

CONCLUSION

Red zoning and red listing help to prioritize the germplasm for rescue. Red zone areas need to be identified as quickly as possible for germplasm rescue. Multi stakeholders with multiple approaches and tools are necessary for germplasm rescue and rebuilding local seed systems in earthquake affected areas. Some of important tools are diversity fairs, participatory seed exchange events, diversity blocks, diversity kits, repatriation, climate analog tools, identification of climate smart germplasm, etc. These tools and processes helped to restore

lost diversity, revive and strengthen the local seed system and safeguard biodiversity of native crops from the red zone areas. Focus should be on providing access and availability of locally adapted varieties and quality seeds of the local crops. Rescue collection during and after disasters in red zone areas of remote mountainous locations was difficult and challenging. Old collections in Genebank and participatory exchange of native seeds from neighboring unaffected areas have been great help to revive the local seed systems through repatriation of seeds of native crop seeds using diverse tools and approaches in the affected red zone areas. The lessons learned from this study implies that the national government, international agencies and funding agencies in disaster prone areas need to consider the use multiple approaches and tools employed in this study to rescue, repatriate and restore lost native agrobiodiversity and strengthen local seed system for quick food security and livelihood recovery of the vulnerable populations.

ACKNOWLEDGEMENTS

We acknowledged the Global Crop Diversity Trust, Rome for financial support through the project, Rebuilding Local Seed System: Rescue Collection, Conservation and Repatriation in Earthquake affected Areas of Nepal" from August 2015 to December 2017. This project was implemented by Nepal Agricultural Research Council in collaboration with the then Bioversity International. Thanks goes to farmers and the then District Agriculture Development Offices of target districts for their cooperation and support to implement the different activities.

Authors' contributions

BKJ and DG conceptualized the project. BKJ drafted the paper and DG revised. KHG, KP, SS and DMSD implemented activities in the field, collected data and analyzed.

Conflict of interest

The authors declare no conflicts of interest regarding publication of this manuscript.

REFERENCES

Chaudhary, P., Bhatta, S., Aryal, K., Joshi, B.K., & Gauchan, D. (2020). Threats, Drivers, and Conservation Imperative of Agrobiodiversity. *The Journal of Agriculture and Environment, 21*, 44-61.

Chaudhary, P., Joshi, B.K., Thapa, K., Devkota, R., Ghimire, K.H., Khadka, K., Upadhya, D., & Vernooy, R. (2016). Interdependence of plant genetic resources in light of climate change. In B.K. Joshi, P. Chaudhary, D. Upadhya, & R. Vernooy (Eds.), *Implementing the International Treaty on Plant Genetic Resources for Food and Agriculture in Nepal: Achievements and Challenges* (pp. 65-80). LI-BIRD, Pokhara; NARC, MoAD, Kathmandu and Bioversity International, Rome; Nepal.

Dongol, D.M.S., Gauchan, D., Joshi, B.K., Ghimire, K.H., Nemoto, K., Sharma, S., Poudyal, K., Sapkota, S., & Khatiwada, S. (2017). Repatriation of Crop Landraces in Earthquake Affected Districts. In B.K. Joshi & D, Gauchan (Eds.), *Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal* (pp. 126-138). Proceedings of a National Sharingshop, 18 Dec 2017, Kathmandu; NAGRC, Bioversity International and Crop Trust; Kathmandu, Nepal.

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

FAO. (1999). *Women: Users, preservers and managers of agrobiodiversity*. http://www.fao.org/3/x0171e/x0171e03.htm

FAO. (2015). *Nepal Earthquake; Agricultural Livelihood Impact Appraisal in six most affected districts*. Food and Agriculture Organization (FAO) of the United Nation.

Friis-Hansen, E., & Kiambi, D. (1998). Re-introduction of germplasms for Diversification of the genetic base of the Somali Agriculture production System. *IPGRI Technical Project Termination Report*. IPGRI, Rome.

Gauchan, D., & Shrestha, R.B. (2020). Community Based Seed Systems for Agrobiodiversity and Resilient Farming of Smallholder Agriculture in South Asia. In R.B. Shrestha, M.E. Penunia & M. Asim (Eds.), *Strengthening Seed Systems - Promoting Community Based Seed Systems for Biodiversity Conservation and Food & Nutrition Security in South Asia* (pp. 29-53). SAARC Agriculture Center, Bangladesh; Asian Farmers' Association, the Philippines; and Pakistan Agricultural Research Council, Pakistan.

Gauchan, D., Joshi, B.K., Ghimire, K.H., Poudyal, K., Sapkota, S., Sharma, S., Dangol, D.M.S., Khatiwada, S., Gautam, S., & Sthapit, S. (2018). Rebuilding local seed system and safeguarding conservation of agrobiodiversity in the aftermath of Nepal 2015 earthquake. *The Journal of Agriculture and Environment*, *19*, 130-139.

Gautam, S., Sthapit, S., Gauchan, D., Dhakal, B., Pudasaini, N., & Yadav, R. (2017). Participatory Seed Exchanges Restore Farmers' Access to Diverse Seeds in the Aftermath of the 2015 Earthquake in Nepal. In B.K. Joshi & D. Gauchan (Eds.), *Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal* (pp. 60-67). Proceedings of a National Sharing shop, 18 Dec 2017, Kathmandu; NAGRC, Bioversity International and Crop Trust; Kathmandu, Nepal.

Gauchan, D., Joshi, B.K., & Ghimire, K.H. (2017). Impact of 2015 Earthquake on Economy, Agriculture and Agrobiodiversity in Nepal. In B.K. Joshi & D. Gauchan (Eds.), *Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas in Nepal*. Proceedings of National Sharingshop, December 16, 2017 Kathmandu, Nepal.

Gauchan, D., Joshi, B. K., Sthapit, S., Ghimire, K., Gautam, S., Poudel, K., Sapkota, S., Neupane, S., Sthapit, B., & Vernooy, R. (2016). Post-disaster Revival of the Local Seed System and Climate Change Adaptation: A Case Study of Earthquake Affected Mountain Regions of Nepal. *Indian Journal of Plant Genetic Resources*, *29*(3), 348–350. https://doi.org/10.5958/0976-1926.2016.00065.6.

Ghimire, K.H., Joshi, B.K., Karkee, A., & Gauchan, D. (2017). Existing Collections and Important Germplasm in Genebank from Earthquake Affected Districts. In B.K. Joshi & D. Gauchan (Eds.), *Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal* (pp. 99-107). Proceedings of a National Sharingshop, 18 Dec 2017, Kathmandu; NAGRC, Bioversity International and Crop Trust; Kathmandu, Nepal.

Guarino, L. Ramanatha Rao, V., & Reid, R. (1995). *Collecting Plant Genetic Diversity. Technical guidelines*. IPGRI/FAO/UNEP/IUCN/CAB International, UK.

Joshi, B.K., Acharya, A.K., Gauchan, D., & Bhatta, M.R. (2017a). Agrobiodiversity status and conservation options and methods. In B.K. Joshi, H.B. KC & A.K. Acharya (Eds.), *Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal* (pp. 21-38). Proceedings of 2nd National Workshop, 22-23 May 2017, Dhulikhel; NAGRC, FDD, DoA and MoAD; Kathmandu, Nepal.

Joshi, B.K., Gauchan, D., Sapkota, S., Dongol, D.M.S., Poudyal, K., Gautam, S., Khatiwada, S., & Ghimire, K.H. (2017b). Red Listing of Crop Landraces in Earthquake Affected

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

Areas. In B.K. Joshi & D. Gauchan (Eds.), *Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal* (pp. 108-125). Proceedings of a National Sharingshop, 18 Dec 2017, Kathmandu; NAGRC, Bioversity International and Crop Trust; Kathmandu, Nepal.

Joshi, B.K., KC, H.B., Tiwari, R.K., Shrestha, P., Amagain, R., & Upadhyay, M.P. (2005). Varietal richness of agricultural crop species and farmers' preferred traits over space and time in Nepal. *Botanica Oreintalis (Journal of Plant Science)*, 5, 69-74.

Joshi, B.K., Upadhyay, M.P., Gauchan, D., Sthapit, B.R., & Joshi, K.D. (2004). Red listing of agricultural crop species, varieties and landraces. *Nepal Agric. Res. J.*, 5, 73-80. http://www.narc.org.np/publicaton/pdf/journal/Vol5/red_listing_agricultural_crop_species_varieties_la.pdf

Joshi, B.K., Gorkhali, N.A., Pradhan, N., Ghimire, K.H., Gotame, T.P., KC, P., Mainali, R.P., Karkee, A., & Paneru, R.B. (2020a). Agrobiodiversity and its Conservation in Nepal. *Journal of Nepal Agricultural Research Council*, 6. 14-33. https://doi.org/10.3126/jnarc.v6i0.28111

Joshi, B.K., Humagain, R., Dhakal, L.K., & Gauchan, D. (2020b). Integrated Approach of National Seed Systems for Assuring Improved Seeds to the Smallholder Farmers in Nepal. Chapter 11. In R.B. Shrestha, M.E. Penunia & M. Asim (Eds.), *Strengthening Seed Systems - Promoting Community Based Seed Systems for Biodiversity Conservation and Food & Nutrition Security in South Asia* (pp.181-194). SAARC Agriculture Center, Bangladesh; Asian Farmers' Association, the Philippines; and Pakistan Agricultural Research Council, Pakistan.

Joshi, B.K., Shrestha, R., Gautam, I.P., Poudel, A.P., & Gotame, T.P. (2019). *Neglected and Underutilized Species (NUS), and Future Smart Food (FSF) in Nepal*. National Agriculture Genetic Resources Center (NAGRC, National Genebank), NARC, Khumaltar, Kathmandu, Nepal.

Joshi, B.K., Vernooy, R., & Chaudhary, P. (2017c). Crop Interdependence, Adaptation to Climate Change and the Multilateral Systems of Access and Benefit Sharing: The Case of Nepal. *Indian Journal of Plant genetic Resources, 30*(3), 210-217. https://doi.org/10.5958/0976-1926.2017.00026.2

Joshi, B.K. (2017). Conservation and utilization of agro-biodiversity advanced from 1937 to 2017 in Nepal. In F. Devkota (Ed.), *Krishi Sanchar Smarika* (pp. 181-208). Agricultural Information and Communication Center (AICC), MoAD.

Joshi, B.K. (2019). Red Zoning and Red Listing of Agricultural Plant Genetic Resources. In B.K. Joshi & R. Shrestha (Eds.), *Working Groups of Agricultural Plant Genetic Resources (APGRs) in Nepal* (pp. 167-173). Proceedings of National Workshop, 21-22 June 2018, Kathmandu; NAGRC, NARC, Nepal.

Joshi, B.K., & Gauchan, D. (2017). Germplasm Rescue: Why and How? In B.K. Joshi & D. Gauchan (Eds.), *Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal* (pp. 41-50). Proceedings of a National Sharingshop, 18 Dec 2017, Kathmandu; NAGRC, Bioversity International and Crop Trust; Kathmandu, Nepal.

NPC. (2015). *Nepal earthquake 2015: Post Disaster Needs Assessment* Vol. A. Key Findings. NPC, Kathmandu, Nepal.

Poudyal, K., Joshi, B.K., Gauchan, D., Sapkota, S., Ghimire, K.H., Dangol, D.M.S., & Adhikari, N.R. (2017). Analogue Sites of Earthquake Affected Areas in Nepal for

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v3i2.32294

Deployment of Climate Smart Rice Landraces. In B.K. Joshi & D. Gauchan (Eds.), *Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal* (pp. 78-88). Proceedings of a National Sharingshop, 18 Dec 2017, Kathmandu; NAGRC, Bioversity International and Crop Trust; Kathmandu, Nepal.

Pudasaini, N., Sthapit, S.R., Gauchan, D., Bhandari, B., Joshi, B.K., & Sthapit, B.R. (2016). *Baseline Survey Report*: *I. Jungu, Dolakha*. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. LI-BIRD, NARC and Bioversity International, Pokhara, Nepal.

Sthapit, B., Gautam, R., Gyawali, S., Joshi, B.K., Subedi, A., Yadav, R.B., Chaudhary, P., & Rijal, D. (2006). Diversity kits: Deploying new diversity to farmers. In B.R. Sthapit, P.K. Shrestha & M.P. Upadhyay. G*ood practices: On-farm management of agricultural biodiversity in Nepal*. NARC, LI-BIRD, IPGRI and IDRC.

Sthapit, B., Rana, R., Subedi, A., Gyawali, S., Bajracharya, J., Chaudhary, P., Joshi, B.K., Sthapit, S., Joshi, K.D., & Shrestha, P. (2012). Participatory four-cell analysis (FCA) for understanding local crop diversity. In B.R. Sthapit, P. Shrestha & M.P. Upadhyay (Eds.), *On-farm management of agrobiodiversity in Nepal: Good practices* (pp. 13-16). NARC, LIBIRD and Bioversity International, Nepal.

Upadhyaya, M.P., & Joshi, B.K. (2003). *Plant Genetic Resources in SAARC countries: Their conservation and Management: Nepal Chapter* (pp. 297-442). SAARC Agriculture Information Centre.