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Review

Approaches and Advantages of Increased Crop Genetic Diversity in the Fields

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Abstract: Crop genetic diversity is the most important factor for a long-term sustainable production system. Breeding and production strategies for developing and growing uniform and homogenous varieties have created many problems. Such populations are static and very sensitive to unpredictable stresses. In Nepal, more than 80% of the seed system is informal, which has contributed greatly to creating and maintaining genetic diversity within the field. This paper aims to assess and present the approaches and advantages of increased crop genetic diversity in the fields, based on the experiences of implementing on-farm conservation activities carried out in Nepal for last two decades. Some of the evidence has been derived from an ongoing evolutionary plant breeding (EPB) project being implemented in Nepal. The information is supplemented with field assessments, focus group discussion, and a literature review. The major approaches to increase crop genetic diversity are evolutionary plant breeding, cultivar mixture, landrace enhancement, informal seed systems, the bulk method, diversifying the seed sources, participatory plant breeding, open pollination, etc. EPB and cultivar mixture are very simple and effective approaches to increase crop genetic diversity at field level. The involvement of farmers in these approaches helps to accelerate the population improvement, maintaining the higher degree of genetic diversity. The major advantages of increased crop genetic diversity are seed maintenance by farmers themselves, minimal risk of crop failure, resilience to unpredictable stresses, increased amount of diversified nutrition, production increment, ease of producing organically, etc. However, there are some issues and problems associated with mixtures and intra-varietal diversity; for example, not being able to harvest by machine, maturing at a different date, difficulty in maintaining seeds and registration, etc. Crop genetic diversity should be considered as a sustainable approach for a climate-resilient and self-dependent production system. The higher the genetic diversity in farming land, the more chance of receiving multiple benefits in the agriculture system.

Keywords: evolutionary population; informal seed system; landrace; resilience; varietal mixture

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1. Introduction

Crop genetic diversity has been created by nature, and managed, utilized and maintained by farmers across the world. Farmers always transfer their crop diversity to the next generations and other farming communities [1,2]. Before the green revolution, genetic diversity was very high in the fields. Even in Nepal, where the modern varieties have not reached, there is higher genetic diversity being maintained by farmers compared to farming areas of modern varieties. It is commonly said by agriculturists that native landraces perform poorly and cannot meet the demands of the human population in the world. As advances have been made in agriculture, the grain yields of a few crops have increased significantly; however, crop genetic diversity in the fields is decreasing [3] and some farmers' rights are being transferred partly to other institutes. Genetic diversity has now been confined in buildings with static conditions and is being exploited by agricultural researchers, especially by plant breeders for their business. For example, the Consultative Group for International Agricultural Research (CGIAR) has more than 700,000 crop accessions collected from different parts of countries. CGIAR uses this diversity for developing better genotypes and then transfers them to farming areas. There are many other private and public organizations that are doing similar business.

Crop genetic diversity in the fields is the most important factor for sustainable and secured agriculture. Farmers have realized the demerits of cultivating uniform and mono-genotyped varieties in a large area. There are many cases of failures of modern crop varieties. Farmers have many traditional practices that help to maintain and increase the crop genetic diversity in the fields. However, these practices are not now in practice in many areas after modern varieties have been adopted. Only a few varieties dominate the farming areas, e.g., the Srijana tomato variety, the Mansuli rice variety, etc., in Nepal. This system also replaced many native and localized crop landraces. Realizing the genetic erosion from the fields, some organizations started working on increasing the genetic diversity in the fields and have developed different approaches that also help to conserve genetic diversity in a dynamic state [4–7]). These approaches are also good for strengthening agroecological services [8,9] as well as for diversifying the produce in households and markets.

This paper, therefore, documents the existing approaches and practices used to increase genetic diversity in the fields, so that this information can contribute to maintaining, increasing, and utilizing diversity across the farming areas. An increased understanding of the importance of genetic diversity will further guide policy and strategy formulation and development [10,11]. The information in this paper is based on the past and current experiences of implementing on-farm conservation and evolutionary plant breeding projects which have been implemented in Nepal in the last two decades and it is supplemented with field assessments along with traditional knowledge and practices, focus group discussion, and literature review. Knowledge gained from the field experiments and interaction with breeders has also been documented. Information was also generated from farmers' field days, national and regional workshops, participatory varietal selection experiments and participatory preferential ranking works carried out over the multilocation and multicrops.

2. Crop Genetic Diversity

Crop genetic diversity includes diversity from domesticated species to alleles. Farmers mostly diversify production domains by using different species, crops, varieties, landraces and trait-specific genotypes. Crop genetic diversity is defined as any variation within and between crop cultivars, including their genotypic and phenotypic characters. Crops are domesticated plants used extensively for human benefit and managed by humans in their agricultural systems, e.g., rice, bean, apple, potato, forage species, etc. Cultivars are crop genotypes that are subject to cultivation practices, and this includes both varieties and landraces. Varieties are crop genotypes developed by breeders and cultivated in farming areas. Landraces are traditional genotypes, locally adapted, genetically altered by nature and maintained by farmers over a long period, and also called farmer's variety. Diversity can be of different types, e.g., intra and inter crop diversity, intra and inter cultivar diversity, intra and inter varietal diversity, intra and inter landrace diversity, etc. Within cultivars, there are two types based on genetic diversity. One is called a monomorphic cultivar, and is uniform, homozygous and morphologically and genetically the same. The other is polymorphic, which is heterozygous with more than one type or different types of forms at both phenotypic and genotypic levels. The variability in these genetic resources (which is governed by many drivers) can be measured using different approaches at different levels [12]. Major drivers of crop genetic diversity are land type, season, market demand, family demand, technology availability, and incentives, etc. Crop genetic diversity has been considered very important for food, nutrition, business, health and environmental security.

3. Diversity in Research and Production Systems

Agricultural researchers collect germplasm (basket of genetic diversity), both native and exotic, including wild relatives from fields and institutes. They also create and maintain diversity through hybridization, mutation, genetic engineering, etc. Much of the diversity has been mostly confined in the buildings, e.g., gene banks or other reservoirs, and only a few selective lines have been used for cultivation purposes due to their high production performance, which has resulted in the narrowing down of crop genetic diversity in the field [2,13]. More-importantly, genotypes in research fields have much less interaction with environmental factors in conventional breeding systems, as most of the research activities are carried out within the research stations. Conversely, participatory plant breeding allows a high level of acclimatization of variety with the target environment as most of the research activities are conducted in the farmers' field. In formal cases, the genotypes are mostly handled and exposed to the chemical production system, i.e., chemical fertilizers and pesticides. The advancement of genotypes is based on a single trait and targeted to make them homozygous and uniform. The various diverse genotypes are discarded, and only a few selected genotypes are used in the research fields. This has resulted in the loss of allelic diversity from the gene pool shared by landraces and other crop cultivars. Thousands of diverse genotypes are discarded each year in the research stations, and therefore a very narrow genetic base population and genotypes are then tested in farmers' fields.

In contrast to the research station, diversity is very high in the farmer-managed production system. Any genotypes have to interact with many different environmental factors for their adoption, as the cultivars ultimately have to be grown in open field conditions. Due to diverse factors in the production fields and households, farmers consider multiple traits. Farmers generally allow nature to select the genotypes for next season's planting. The diversity found, therefore, is higher in crops managed by farmers from seeding to storing seeds by themselves in comparison to crops that are taken from a formal seed system. Phenotypic variability, including off-types (of the same crop), is continuously retained in informal seed systems, which helps to create and maintain genetic diversity. Additionally, in the production system managed through the formal seed system, some farmers' rights have been knowingly or unknowingly transferred to other seed companies, e.g., the production and marketing rights of seeds of different classes. In this system, seeds are produced in different locations, other than grain production sites, (which may be far from the grain production domain). This may sometimes cause an environmental shock to varieties in the production system.

4. Approaches for Increasing Diversity

During the field visit, focus group discussions, and interaction with farmers, several different approaches and methods (Table 1) were found in farming and research areas to increase genetic diversity in many different crops. Some approaches are traditional, and some have been developed by researchers and transferred to farmers. These approaches are practiced by farmers mainly on rice, wheat, maize, bean, oilseed crops, vegetables, finger millet, foxtail millet, barely, proso millet, amaranths, soybean and other grain legumes. Some approaches look very simple but help significantly to maintain and increase the diversity in the fields. Farmers, growers and researchers who love genetic diversity are following these approaches and producing benefits. These approaches look highly practicable for the on-farm conservation and restoration of crop biodiversity. Germplasm exchange and repatriation based on climate analog tools are also very effective to obtain higher production and conservation of diversity in the fields. Multiple approaches might be good to use even in a single landrace for producing higher benefits as well as to accelerate their conservation on-farm [14,15].

Table 1. Approaches for increasing crop diversity in the fields.

Scheme	Approach	Explanation and Applied Crop Groups	Remarks
1.	Bulk method	Bulking of seeds from different plants, and/or from different fields, blocks, plots and plants. In cereals and grain legumes	Some farmers have more than one separate field to grow crops which helps to bulk the seeds from different fields
2.	Bulk seed processing	Crop harvesting together for both seeds and grains from all fields and threshing, cleaning, drying and storing together. In cereals and grain legumes	No selection and separation of seeds for next season's planting
3.	Classes-bulking selection	Making different classes of crops in the field, selecting within classes, and mixing selected seeds from all classes. In rice and bean	Classes can be made based on the farmer's preferred traits and other important morphological traits, seed color, size, etc.
4.	Community genebank	Many different landraces are made available to the local community. They also conserved the same landraces from different farmers and sites. In cereals, grain legumes, and vegetables	It also includes a community seed bank and facilitates the exchange of seeds, and adds new collections. Mixed seed collection from different farmers helps to increase diversity
5.	Crossing	Hybridization of two or more different genotypes to obtain segregating lines. In rice and maize	Segregating lines provide diversity selection options
6.	Cultivar mixture	Growing more than one landrace/variety together in the same fields. In cereals and grain legumes	Continuous mixing can help generate new genotypes
7.	Multiple sources for seeds	Different seed suppliers can provide many different genotypes of the same crops. Seed sources from the local shop, relatives, neighbors, community seed bank, market, etc., help to increase the diversity. In cereals and vegetables	Informal seed sources supply broad genetic base materials, whereas formal seed sources generally supply uniform varieties
8.	Diversity block	Many blocks or plots of different cultivars within a field. In cereals	It provides diversity to farmers for selection and helps maintain the diversity within a targeted locality
9.	Diversity fair	Display of all crops and their seeds/germplasm by many farmers in one place at a certain time. In cereals, grain legumes and vegetables	All available crop diversity can be seen, exchanged and traded
10.	Diversity field school	Farmers and experts discuss and observe crops diversity in the field. In cereals	Similar to farmer's field school, but focuses on genetic diversity
11.	Diversity kit	Planting pack with a mini pack of many different crops' seeds. In cereals, grain legumes and vegetables	It includes the elite line, released variety and native landraces of many suitable crops
12.	Evolutionary plant breeding	Mixing and growing many more (>10) landraces and varieties together, focusing on developing dynamic mixture population or by using many segregating or recombinant inbred lines. In rice and bean	Very easy way to conserve crop biodiversity through uses
13.	Informal seed system	Exchange or marketing of seeds among farmers without any formal regulations. In cereals, grain legumes, vegetables and fruits	The very old system exists in many communities for multiple crop species
14.	Insect-friendly farming system	Ecological agriculture favors insects which help to pollinate and maintain genetic diversity. In maize, oil seed crops and vegetables	Insect field genebank accelerates pollination in many crops
15.	Landrace enhancement	Participatory selection of landraces for their genetic improvement. In cereals and grain legumes	Farmers prefer to grow landraces if their genetic performance enhanced
16.	Mass selection	Selection of particular seeds from different plants and mixing them. In cereals and grain legumes	Simple and common practices, but effective in large population size
17.	Mix cropping	Growing more than one crop in the same field. In maize, finger millet, pumpkin and cowpea	Increased diversity at species levels
18.	National Genebank	Collection of all types of crop diversity from around the country and distribution to farming communities. In cereals, grain legumes, vegetables and oil seed crops	Useful to repatriate the landraces as well as to establish diversity blocks in the target location
19.	Negative selection	Removing seeds or plants that are not suitable or cannot produce seeds very well. In vegetables	Selection pressure is very low
20.	Open pollination	Pollination and fertilization go naturally. In cereals, grain legumes, vegetables and oil seed crops	Pollinators help to accelerate the creation of genetic diversity
21.	Participatory plant breeding	Involvement of farmers and breeders in selection and evaluation, including hybridization and handling of segregating lines. In rice, wheat and buckwheat	Segregating lines are generally handled in a target environment

Table 1. *Cont.*

Scheme	Approach	Explanation and Applied Crop Groups	Remarks
22.	Participatory seed exchange	Event for farmers in a certain place to exchange seeds of mainly rare, endangered landraces. In cereals, grain legumes and vegetables	Organize during seed scarcity, i.e., after the earthquake, flooding, etc.
23.	Participatory varietal selection	Growing of a few fixed genotypes (generally 5-10) in farmers' fields along with local in farmers' management system. In rice, wheat, maize and grain legumes	Farmers can select more than one variety. Different farmers can select a different variety
24.	Repatriation	Growing of landraces that were available in the past but not now. Additionally, a climate analog tool can be used to identify the suitable germplasm to repatriate the climatically smart germplasm. In rice, bean, proso millet and foxtail millet	Such materials can be collected from the National and Global Genebank. Landraces can be collected from climatically analog sites
25.	Multiline variety	Growing more than one different line. In rice and bean	Usually, these are breeding lines and differ from each other for certain traits
26.	Near isogenic lines	Lines that are genetically identical except for the allele at one locus. In rice	Applicable to mostly for monogenic traits
27.	Site-specific variety	Development and maintenance of a variety for a particular site. In cereals and grain legumes	A large number of different varieties are needed for a diverse agroecosystem
28.	Growing the same variety over a time	Growing the same variety over a period in the same field for different generations. In cereals, grain legumes and oil seed crops	Selection choices and mutation along with natural crossing create and maintain diversity
29.	Hybrid swarm	Cultivated varieties may cross with wild relatives available near to the field and grow their progeny in the field. In rice and wild rice	It is common in rice that crosses with wild rice available near the field. Many different genotypes can be observed in the next generation
30.	Shattered seeds and off-types in the next season's plant population	During harvest in some crops, seeds fall in the field and grow together the next season with a seeded plant population. Off types are also included in the farming system. In rice, wheat and finger millet	This favors growing both in situ and on-farm materials together
31.	Manual weeding during flowering and multiple harvests	Manual weeding during flowering helps to pollinate the flowers by shaking plants. Similarly, when picking fruits, seeds in indeterminant plants may shake plants to pollinate. In maize and oil seed crops	Weeding and traveling during flowering accelerates the cross-pollination
32.	Natural selection	Growing landraces with minimum human interferences and survival of the fittest applied. In cereals and grain legumes	No selection during harvest and seed cleaning
33.	Parent–offspring mix plantation	Growing parental lines and their offspring together in the same field. In finger millet, sponge gourd and cucumber	Farmers sometimes mix newly harvested seeds with the previous year's seeds
34.	Ethnicity specific variety	Ethnic groups need different crops and landraces for their cultural and religious purposes. Based on their requirements, variety is developed and grown. In cereals	Diverse ethnic groups live together and may have different genotypes
35.	Natural agents for translocating planting materials	Sometimes, natural factors/agents, e.g., birds, insects, wind and flood, transfer seeds and other planting materials from one location to another. In wild rice, amaranth and proso millet	New genotypes can be observed in the fields and harvested together with normal plants

Note: This table is based on the experiences of farmers, authors, and a brief interview with agrobiodiversity-rich farmers and researchers.

For increasing diversity, farmers' practices are, relatively, better than modern agricultural practices. When creating diversity in the fields, different multiple traits should be considered for the selection of genotypes. Trait-based selection for mixing landraces and varieties depends on the biotic and abiotic stresses (Table 2). For example, different root-length cultivars are suitable for cultivation in drought areas. However, maturity and cooking methods should be the same for all mixed landraces and varieties. In the case of the in-determinant type, maturity is not applicable for consideration.

Table 2. Important traits for mixing cultivars (landraces and varieties) against different conditions.

For Space Use (All Dimensions)	For Disease and Insect Pests	For Drought	Similarity in Traits
• Different root lengths and textures • Different plant height • Different plant structures and shape • Different sizes and canopy	• Different reaction capacities with insect pests and diseases • Different leaf and stem textures • Different colors and sizes • A different scent, and secondary metabolites	• Deep root • Erect plant/leaf • Different plant heights and canopy • Large but few leaves	• Maturity • Cooking method and time • Milling

5. Advantages of Increased Crop Diversity

Increased diversity in the field ensures the harvest and minimizes the risk of crop failure due to both biotic and abiotic factors [16,17]. Crop diversity contributes to yield stability and insect and pest resistance/tolerance due to a broad genetic base derived from diverse germplasm sources [18,19]. A few advantages associated with high intra-varietal diversity are given in Figure 1. Jumli Marshi (Figure 1 left) is highly polymorphic and as a result we have observed less disease pressure as well as a low vulnerability to climate-related abiotic stresses. Due to climatic variations and the requirements of different products to meet the preference of clients, the majority of farmers in Nepal grow a large number of crop species and their varieties as well as landraces. Growing varieties of the same crops is easy and also provides multiple benefits. This is very important for sustainable agricultural businesses maintaining a functional agroecosystem. Many farmers are very familiar with the advantages of increased crop diversity in the fields. In many areas, we observed that farmers grow different crop species together as well as mixed populations of varieties and landraces (Figure 2). Some practices of farmers are given in Table 3, along with their advantages. Farmers keep seeds from such mixed populations for the next season, which favors natural selection. Alongside this, they are resilient to climate and other environmental factors [20], including weeds [21], and perform, relatively, better than other newly developed narrow genetic base varieties.

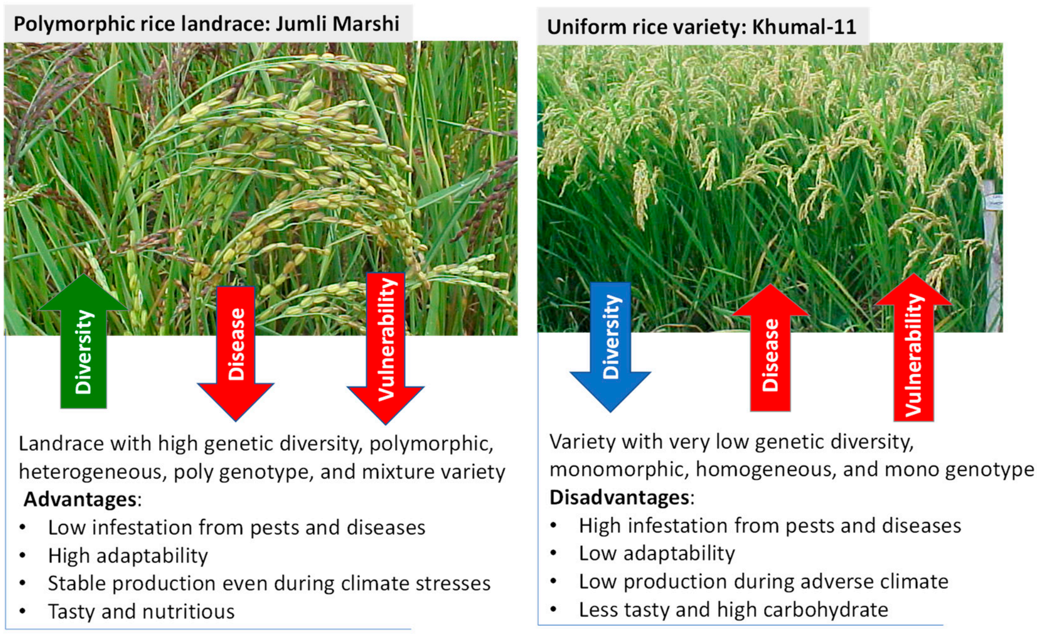

Figure 1. Advantages and disadvantages of polymorphic and uniform cultivars. Arrows indicate either an increase (**up arrow**) or decrease (**down arrow**) in the trait included in the arrow box.

Figure 2. Genetic diversity in the field: (**A**) Crop mixture (rice + foxtail millet + brinjal and others) in Humla district, (**B**) three sister crops (maize, pumpkin and bean) in East Nepal, (**C**) two bean landraces in Jumla and Rukum districts, (**D**) evolutionary rice population in Jumla district (50 rice landraces).

Table 3. Farmers' practices of mixing landraces and varieties of bean, finger millet and rice in Nepal.

Crop	Mixing Components	Site	Advantages
Bean	>20 landraces	Jumla	Less damage from diseases (anthracnose, rust, leaf spot, blight, etc.), 2–3 months continuous harvest, tasty
Finger millet	Dalle Kodo + Bhotyangre Kodo + Chyalthe Kodo	Jugu, Dolakha	High yield, good forage, fewer diseases (blast, smut, blight)
Rice	Kali Marshi + Chandanath-1 + Chandanath-2	Jumla	Less damage by blast, taste remains as local landrace
Rice	Gurdi + Mansara	Pame, Kaski	Better even in drought condition, less damage by insect pests and diseases
Rice	Kalo Patle + Machhapuchhre-3 + Lekali	Dhikur Pokhari, Kaski	No damage by a monkey, higher grain yield, less damage by disease, no lodging
Rice	1. Mana Muri + Sano Gurdhi, 2. Kathe Dhan + Panhele, 3. Thimaha + Anga + Mansara, 4. Kalo Patle + Chommrong + Machhpuchhre-3	Kaski	Lodging tolerant, less damage by insect pests and diseases, tasty, high grain yield

Source: [17].

The Figure 2 depicts traditional farmers practices of growing mixtures of crops on the same piece of land (Figure 2A), such as rice, foxtail millet and brinjal (eggplant or aubergine); the mixed cropping of maize, pumpkin, and beans in East Nepal (Figure 2B); seeds harvested from diverse beans in the Jumla and Rukum districts of Nepal (Figure 2C); and a mixture of rice composed of over 50 landraces grown on the same plot (Figure 2D).

Mixtures are planted deliberately to avoid the complete failure of farms in case of the occurrence of biotic and abiotic stresses (Figure 1; Table 3).

6. Practices for Narrowing Diversity

Farmers' traditional knowledge and practices favor creating and maintaining both intra and inter-varietal diversity. However, as advances are made in agriculture, many practices are moving towards narrowing genetic diversity. For example, plant breeders test and evaluate only the selective genotypes in many locations and countries. Genotypes that perform well in multiple sites are promoted and integrated into the formal seed system [22]. The promotion of stable genotypes based on genotype by environmental interaction across the world leads to the narrowing of the genetic diversity in the fields. CGIAR-based materials are tested in a similar fashion. This system also includes the collection of as much diversity as possible from the fields and stores in the buildings and then the expansion of a few high-yielding varieties (uniform and monogenotype) in many areas. The recommendation of a single variety in a large area in many countries drastically replaces the many site-specific crop landraces.

In many breeding institutes, a single breeder leads the breeding work and a narrow perspective dominates the breeding process. The majority of breeding work focuses on a single trait, i.e., grain yield. Neither single-led breeding work or single-trait-based breeding programs could broaden the genetic base across the locations [10]. Research and development in these institutes also focuses on only a few selected crops. Due to this, the geographical coverage of a few crops is increasing, resulting in the cultivation of narrow diversity at species and varietal levels. The dissemination method of newly developed varieties, along with incentives, also promotes narrow genetic base varieties. Farmer field trials (FFT) and minikit are very common methods adopted by many countries to disseminate varieties. The expansion of growing F1 hybrid and genetically engineered varieties is very high. All of these varieties are practically non-evolutionary and therefore cannot maintain genetic diversity in the field. Other breeding methods, e.g., pure line selection, pedigree methods, backcross, etc., also develop very narrow genetic base varieties.

On the other hand, sources of planting materials are dominated by a few companies. Covering large areas with a single source of seed supplier leads to genetic erosion from the fields. In fruit species, the use of the same rootstock for large numbers of varieties, as well as clonal propagation, has also drastically reduced and narrowed down the diversity. Similarly, mechanization is another practice that triggers the growth of uniform varieties. Many breeding works also targeted the development of homogenous varieties so that mechanized farming could be possible. The policy also favors uniform and distinct varieties. The system of the distinctness, uniformity and stability (DUS) test promotes homozygous varieties rather than increasing the diversity in the fields.

7. Impact of Narrow Genetic Diversity

Narrow genetic diversity is mainly due to the replacement of landraces by modern varieties. Modern varieties have very low intra-varietal diversity compared to landraces [23]. Selection responses in such narrow genetic diversity are almost negligible. Because of the lack of buffering capacity, these varieties are vulnerable to both biotic and abiotic stresses [15,20] and there are many cases of a complete failure of production in many crops. In addition. insect pollinators prefer to visit fields where diversity is high, both at intra- and inter-varietal levels. Ecological services from such a narrow genetic base are very poor. Very specific parts (i.e., above and below ground) are exploited all the time if the same narrow genetic base varieties are grown over time. If farmers keep seeds for the next generation themselves the performance may reduce, and with it the formal system target to increase the seed replacement rate each year. This also indicates the detachment of farmers' rights from their age-old rights.

The environment, growing conditions, and everything in the production system keeps changing. Many different types of living organisms become connected due to which agroecosystem and soil remain balanced and functional. The narrow genetic varieties are not evolutionary, and natural selection does not work. Nutritionally, the products from such varieties are high in carbohydrates and low in other important nutrients compared to landraces [24]. The narrowing of crop genetic diversity also limits plant breeding [25], genetic advancement such as marker assisted selection [26] and disease resistance enhancement in crops [27].

8. Policy Dimension

In Nepal, there are three types of seed systems, namely formal, informal and non-formal. The formal system handles released and registered varieties under the National Seed Board. An informal seed system ensures the exchange and transfer of very diverse and heterozygous landraces generation after generation, which means it is a carrier of genetic diversity. However, for the integration of any variety into a formal system, it has to be uniform and homozygous as per the existing seed regulation, which highly discourages cultivar mixture and landrace diversity. A formal seed system is the utmost for the commercial production and marketing of any crop varieties and landraces. Any type of genetic variation at species and varietal levels is not favored by the existing seed policy. Incentives are also not provided for non-registered landraces and cultivar mixtures. In the formal seed system, farmers are mostly excluded to multiply seeds of some seed classes, e.g., breeder seeds and foundation seeds, due to requirements of universities degrees and well-managed seed processing infrastructures. This also discourages farmers from continuously engaging in seed sectors, especially for maintaining on-farm diversity. This is also a situation detaching farmers' rights from farmers and increasing their dependency on other agencies for seeds and other inputs. There is also a debate on treating landraces either as public or private goods for farmers, but many private companies and institutes handle varieties as private goods. Still, many farmers have very unique landraces with high genetic variation; therefore, policies should favor the promotion and maintenance of genetic variation at field level, and landraces should be private goods.

9. Conclusions

Genetic diversity in the fields has been decreasing since the Green Revolution. Crop diversity is stored statically in confined areas called genebanks, whereas uniform and homozygotic varieties are increasingly covering the farming areas. Globalizing the crop genetic resources and then favoring widely adapted varieties across the world has resulted in a very narrow genetic base in formally developed crop varieties. However, genetic diversity is most important for securing crop harvests even under adverse climatic and biotic stresses. Many farmers and agriculturists are now increasingly realizing the necessity of maintaining genetic diversity in the fields. Many different approaches have therefore been developed, restarted and applied in major crop species, e.g., rice, wheat, barley, bean, finger millet, etc. As the diversity increased in the fields, their evolutionary rate also enhanced to where better genotypes could be produced and selected for the next generation. Some approaches are also very effective to help farmers to save seeds from their own fields for next season's planting. Ecological and evolutionary approaches should be considered worldwide for every crop species to increase the diversity in the fields.

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