Chapter 7
Dynamics of On-Farm Land Use Changes in Terms of Inter-Specific Crop Diversity: A Case Study of Panipat District of Haryana State, India

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Abstract Crop diversity forms a significant component of the Agro-biodiversity. This is believed to be the result of thousands of years of farmer's selection, experimentation and propagation of desirable traits of desirable species in innumerable ways for their subsistence and cultural purposes. But the selection results in detrimental on-farm land use changes that directly contribute to crop diversity loss. Therefore, this study aimed at determining the existing reality of the on-farm land use changes around the inter-specific crop diversity. The Herfindahl–Hirschman and Simpson index have been used to quantify the concentration of crop type and richness and evenness in crops on the farms. The findings indicated the shift from multiple cropping to monoculture system i.e. Rice Wheat Cropping System (RWCS). Other crops (cash crops, fodder crops, vegetables and pulses) are no more farmers' attraction. This has now become the backbone of farming in the Panipat district. It is ultimately led to inter-specific crop diversity loss. It makes the national authority to think about the issues of sustainability. Many national organizations are working towards safeguarding the crop species and cause farmers to diversify towards other species.

Keywords Agro-biodiversity • Crop diversity • Land-use change • Monoculture • Multiple cropping • Sustainability

7.1 Introduction

The land-use pattern, of which the cropping pattern forms a part, has always been a dynamic phenomenon (Singh 1992b). The crop pattern in any region can't remain static due to the fluctuations in the rainfall and nature of inputs and environmental

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instability (Vaidya 1997). This dynamic on-farm land use brings spatial and temporal changes in crop diversity, which is one of the principal elements of the agro biodiversity. According to the Convention on Biological Diversity (2000), agricultural biodiversity includes all elements of biological diversity of relevance to food and agriculture, and constitute the agro-ecosystem: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes. Crop Diversity is defined as “the variability in genetic and phenotype characteristics of plants used in agriculture.” Crop diversity on farms has both inter-specific (among crops) and infra-specific (within a crop) components (Bellon 1996). In agricultural system, biodiversity performs ecosystem services beyond production of food, fiber, fuel and income. Biodiversity is necessary in the recycling of nutrients, control of local micro-climate, regulating the local hydrological process, regulation of the abundance of undesirable organisms and detoxification of noxious chemicals (Altieri 1999).

According to Global Crop Diversity Trust, crop diversity is disappearing from the fields as farming systems is changing and farmers are abandoning their traditional varieties. Further, increasing homogenization of agricultural production has led to widespread cultivation and rearing of fewer varieties and breeds for a more uniform, less diverse, but more competitive global market (Kameri and Cullet 1999). Panipat district of Haryana state in India has also shown the similar undesirable changes in inter specific crop diversity that contributes to depletion of crop species. It in turn disturbs the agro-ecosystem balance and put pressure on the available natural resources. The on-farm land use has changed after the advent of green revolution in India. Thus, aim of the study was to highlight the results from the study carried out towards on-farm land-use changes in inter specific crop diversity in the Panipat district of Haryana. The study emphasized on two aspects: the first aspect included the on-farm land-use changes in inter-specific crop diversity using data of share of crop area of all crop species to the total crop area within the territorial dominion in both monsoon (Kharif) and winter (Rabi) season. Focus is given to inter specific crop diversity because of non-availability of data on infra specific diversity in the district. The second aspect was to calculate the Herfindahl–Hirschman to quantify the concentration of crops and Simpson index to take into account richness and evenness in crops on the farms.

7.2 Study Area

Panipat district in northeastern Haryana is flanked by River Yamuna on the eastern edge. It is located between 29°09′15″:29°27′25″ North latitudes and 76°38′30″:77°09′15″ East longitudes, with an average altitude of 220 m. It is surrounded by Karnal district in North, Jind district in West, Sonipat district in the South (Haryana) and the Mujarfarnagar district of Uttar Pradesh in the East (Gulati 2005) (Fig. 7.1)

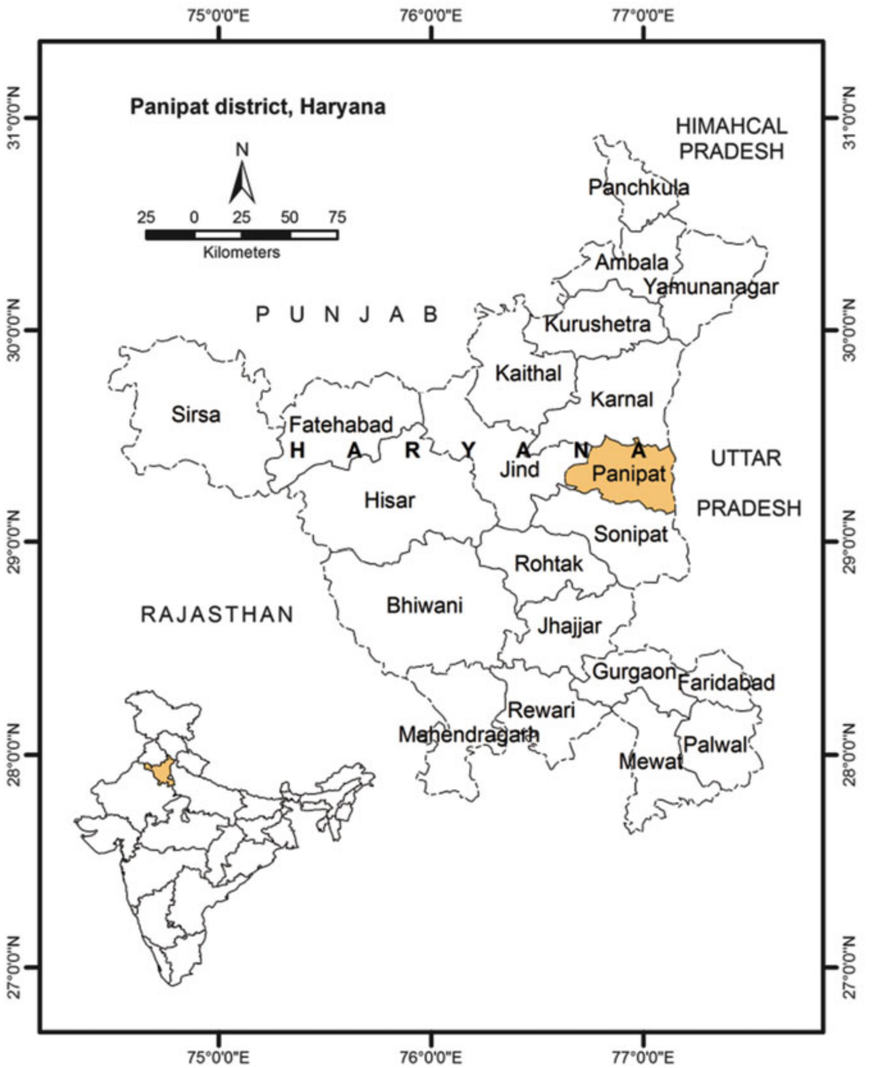

Fig. 7.1 Location of the study area

It also forms the part of Delhi National Capital Region (NCR). The geographical area of the district is 1,304.372 km^2 including 30.28 km^2 under forests and 240.052 km^2 under non-farm use. Agriculture is the mainstay of the district economy. Approximately 78 % of the total geographical area is cultivable of which 98 % is actually cultivated. The cropped area is 1,928.52 km^2 with a cropping intensity is 194 % (Dahiya et al. 2011). The district has enough drainage facilities. The district is drained by Yamuna River and its tributaries. The discharge of the river is high during the monsoon as it gets water from the southwest monsoon. The water of the river and drains may be harvested for crop production. The annual average rainfall over the area is less than 700 mm in the western part and more than 750 mm in the eastern region. The district has two types of soils via-tropical arid brown and arid brown soils. The tropical arid brown soils are found in the northeastern part of the district, especially in parts of Bapoli and Panipat block and remaining area is covered by the arid brown soils. The district has all desirable agro-climatic conditions for agricultural production. Wheat has traditionally been, and continues to be, the mainstay of food security and is grown in the cool and dry winter season. Over the last 30 years there has been widespread adoption of rice that is mainly grown in the hot and wet monsoon season (Erenstein 2011).

7.3 Data Sources and Method

Cropping pattern data had been taken from the district agricultural department of Haryana. The study was conducted in the Panipat district of Haryana in India. Locational factors were taken into consideration during survey. The simple random sampling technique was employed in the selection of respondents. These included both large and small-scale farmers in the district. Focused group discussion, key informant interview, informal discussion and semi-structured interview were conducted for better understanding. The Herfindahl–Hirschman Index, from the marketing industry index of market concentration has been used to quantify the concentration of crop type (Bradshaw 2004; Rahman 2009a; Rahman 2009b, Table 7.1). Simpson index is also calculated which is also a measure of biodiversity that takes into account richness and evenness. The collected data have been analyzed using simple statistical techniques and various graphical methods.

Table 7.1 Crop diversity index used (Bradshaw 2004 and Rahman 2009a)

Index	Concept	Construction and explanation	Interpretation
Herfindahl–Hirschman	Concentration of crops	$D_h = \sum \alpha^2 j$ $0 \leq D_h \leq 1$ Dh = Herfindahl diversity index aj = area share occupied by the jth crop in A A = total area planted to all crops	A zero value denotes perfect diversification and a value of 1 denotes perfect specialization. Thus, a negative sign of the index indicates a positive relationship with diversity
Simpson	Degree of richness and evenness of crops	$SI = 1 - D_h$ SI = Simpson index	The value of this index also ranges between 0 and 1, but the greater the value, the greater the sample diversity.

7.4 Results and Discussions

7.4.1 On-Farm Land Use Changes and Crop Diversity

The district has two cropping seasons via monsoon (Kharif) and winter season (Rabi). Crops were classified as cereal crops, fodder crops, cash crops, vegetables and pulses to look at the on-farm land use changes in the district. Table 7.2 shows the cropping pattern of monsoon from 1950 to 2012. During monsoon season in 1950–1951, cereal crops (53.25 %) were dominant crops followed by fodder crops (24.70 %) and cash crops (16.49 %). Among cereals crops, Bajra crop (26.70 %) was more concentrated followed by Rice (26.55 %). The remaining cropped area was covered by other crops. In 1960–1961, situation was almost similar. Then, Green revolution technology came around 1965–1966. It was implemented in the green belt region of India includes Haryana, Uttar Pradesh and Punjab. It changed the on-farm land use. It is also visible in both the table. Area under cereal crops drastically changed during 1970–1971. During this period, the area under cereal crops increased to almost 63 %. Rice (51.91 %) became dominant crops followed by Bajra (12 %). But, fodder crops shown a decline. Thereafter, Rice crop had increased in the area in comparison to other crops. In 2011–2012, area under cereal crops increased by 59.57 % followed by cash crops (6.84 %), fodder crops (3.36 %), vegetables (1.78 %) and pulses (0.67 %). Area under rice had increased while remaining crops shown a decline in the area. Cotton, maize and oilseeds had vanished from the farm.

On the other hand, during winter season in 1950–1951, pulses covered major area (54.90 %) of the total cropped area followed by cereal crops (39.54 %), oilseeds (4.65 %) and vegetables (0.91 %). The cropping pattern was almost similar during 1960–1961. Then, during 1970–1971, area under cereal crops increased many folds. Cereal crops covered 73.57 % followed by pulses 18.74 % and remaining crops covered almost 7 % area. The wheat crop was dominant among cereal crops. Since then, the area under wheat has increased. During 2011–1912,

Table 7.2 Per cent of area to total cropped area during monsoon season (Kharif) in the district

Crops	1950–1951	1960–1961	1970–1971	1980–1981	1990–1991	2000–2001	2011–2012	Increased/decreased
	Area to total cropped area (in percent)							
Rice	26.55	30.22	51.91	76.17	80.88	81.30	86.12	59.57
Bajra	26.70	29.70	12.00	3.60	2.10	0.42	1.12	−25.58
Sugarcane	8.65	9.65	10.05	7.72	8.40	6.16	6.84	−0.81
Cotton	7.84	5.84	4.00	2.06	1.05	0.04	0.00	−7.84
Maize	1.01	6.80	15.00	6.18	1.05	0.01	0.00	−1.01
Fodder	24.70	14.20	5.00	1.54	1.05	9.98	3.36	−21.34
Vegetables	1.54	1.00	1.00	1.13	2.31	1.48	1.78	−0.76
Pulses	0.01	0.09	0.58	1.03	2.52	0.31	0.67	0.66
Oilseeds	3.00	2.50	0.46	0.57	0.63	0.30	0.11	−2.89

Table 7.3 Percent of area to total cropped area during winter season (Rabi) in the district

	1950–1951	1960–1961	1970–1971	1980–1981	1990–1991	2000–2001	2011–2012	Increased/decreased
Crops	Area to total cropped area (in percent)							
Wheat	37.6	44.1	70.8	84.2	89.2	91.2	95.5	57.86
Barley	1.90	3.00	2.76	1.21	2.76	0.05	0.00	−1.90
Fodder	0.00	2.00	3.35	6.85	4.42	6.08	2.20	2.20
Oilseeds	4.65	5.00	4.14	1.21	0.63	0.78	1.10	−3.55
Pulses	54.9	44.9	18.7	6.05	2.13	0.13	0.55	−54.35
Vegetables	0.91	1.00	0.20	0.40	0.79	1.68	0.66	−0.25

area under wheat has increased by 57.86 % i.e. 95.50 % and remaining crops cover 4.5 %. Area under pulses has declined by 54.35 %. Barley crop has also shown a decline (Table 7.3).

In both the season, area under rice and wheat crop has changed radically. There are some crops such as sugarcane and mustard that were grown individually but now they are raised with other crops. For instance, Sugarcane is grown in combination with Onion and Mustard is grown in combination with Barseem. The competition between Rice and Sugarcane is more than any other crop in area.

Nevertheless, Rice Wheat Cropping System (RWCS) has emerged in the district because of the new agricultural technologies, including irrigation facilities, improved seed varieties, pesticides, insecticides and new methods of farming (Singh 2000). Increase in irrigation facilities has led to a shift in cropping pattern in favor of those crops that have the highest response to irrigation, such as rice and wheat. Likewise, the availability of high-yielding/improved varieties has also been responsible in bringing change in cropping pattern (Singh 1992a). Therefore, wheat dominates the cropping pattern in winter and rice during the monsoon season (Erenstein 2011). Moreover, introduction of new high-yielding varieties of seeds, irrigation installations and technical know-how is responsible for temporal changes (Vaidya 1997). Besides these factors, value of productivity and profitability of crops have been discovered to be the most important (Singh 1992a) as cultivation of wheat and rice in the rotation gives farmers the best combination for getting the maximum benefit from cultivation (Singh 2000). Thus, monoculture cropping system has developed on the farms.

7.4.2 Diversity Index

The Herfindahl–Hirschman and Simpson Index value indicates the temporal and spatial variations in inter-specific crop diversity from 1950 to 2012 during both the cropping seasons. Figure 7.2 shows Herfindahl–Hirschman and Simpson's Index of monsoon season. Herfindahl–Hirschman index value varies between 0.22 (1950–1951) to 0.75 (2011–2012). It reflects that the concentration of species has increased and moved towards the specialization. Change was drastic after

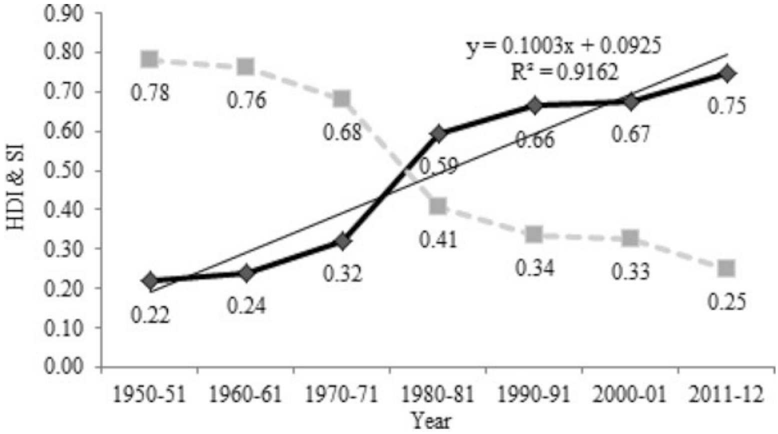

Fig. 7.2 Herfindahl–Hirschman and Simpson's Index of monsoon season in the district. *Black marked line* shows Herfindahl Diversity index (HDI) and *dotted line* shows Simpson Index (SI). *Straight line* without markers shows linear line with equation

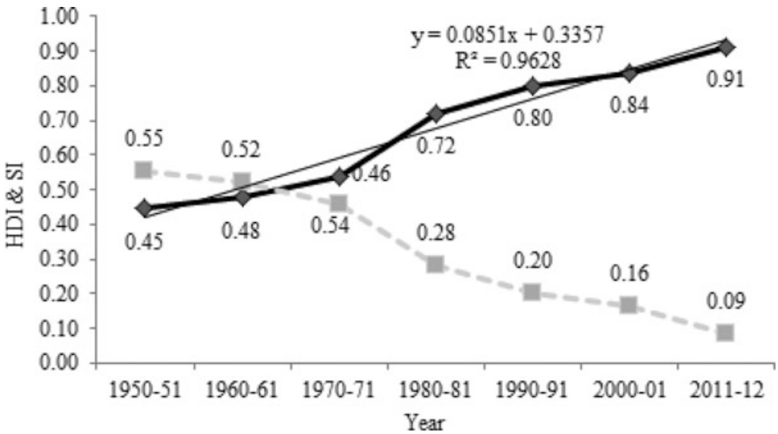

Fig. 7.3 Herfindahl–Hirschman and Simpson's Index of winter season in the district. *Black marked line* shows Herfindahl Diversity index (HDI) and *dotted line* shows Simpson Index (SI). *Straight line* without markers shows linear line with equation

1970–1971. Simpson index is opposite to Herfindahl–Hirschman index. That is why; both curves in the graph intersect each other Simpson index value ranges between 0.78 (1950–1951) to 0.25 (2011–2012). It reflects that the habitat is low in species, so a small change to the environment would have a serious impact.

Data prove that the area is also low in species (Fig. 7.3).value ranges between 0.45 (1950–1951) and 0.91 (2011–2012). Here value is almost near to 1. That means there is homogeneity on the farm. Likewise Simpson's Index value varies between 0.55 (1950–1951) and 0.09 (2011–2012). It shows that the area is also low in species. A high value for Simpson's Index is 'good' and means the area is diverse, species richness, and able to withstand some environmental impact. But a low value is 'poor' and means the area is low in species, so a small change to the environment would have a severe impact. Thus low diversity index value in both the seasons is an issue of concern that requires immediate attention.

The on-farm land use change results in depletion of inter-specific crop diversity. Changes in the number of species grown in the area are shown in Table 7.4. Crop species grown in the district had decreased since 2001 in both the cropping seasons. During monsoon, total numbers of crop species were 39 in 2000–2001. This number decreased to 32 in 2011–2012. Similarly, during winter season, total numbers of crop species decreased from 29 (2000–2001) to 25 (2011–2012). Rice, wheat, sugarcane and forage crops (bar seems and sorghum) are the major crops of the district (Dahiya et al. 2011). Among cash crops, sugarcane is the dominant crop followed by mustard and cotton. Mustard and cotton in the coming years would be completely lost if the trend remains the same. Sunflower has vanished from the farms. Likewise, rapeseeds and Tara Mira are also disappearing from the farms. These two are genetic varieties of mustard. Though pulses can be found out on the farms, but their area had depleted since last decade. Gram, Channa, Moong, Cow-Pea, Mash and Arhar are still grown. Yet, despite this fact, the cropped area has decreased under all these crops. Chana is almost lost from the farms. Among fodder crops, Barseem is widely grown on farms in comparison to others. In fodder crops, Gwar, labia and Javi are also disappearing from the farms. Vegetables stand third in comparison to other crops. These are grown on large area around the urban centers to fulfill their daily need.

7.5 Need for Conservation and Management of Crop Diversity

Conservation agriculture can enhance water productivity, but is unlikely to produce the difference by itself. Alternatively, there is a pressing need to enhance incentives for farmers to use water wisely, although so far the political will has been lacking (Erenstein 2009). Modern agricultural practices strongly favor the reduction of crop diversity by offering the subsidies for cultivating high-yielding varieties and reducing weeds/wild plant diversity by using crop protection measures. This diversity may be preserved by providing positive incentives to local communities (Gadgill et al. 1996). There is scope for reducing the distorted incentives that encouraged the injudicious use of resources-a case in point being the unsustainable water use and lack of crop rotation in rice-wheat systems (Erenstein 2011). Assessment of loss of diversity in farming systems using continued analysis of land-use patterns should be the thrust areas (State of Plant Genetic Resources for Food and Agriculture in India (1996–2006): A Country Report 2007). Diversification of agriculture with alternative land uses can help maintenance of both biological productivity and profitability (Rajput 2006). Diversification involves both enterprise allocation decisions as well

Table 7.4 Changes in number of crop species in the district

	Monsoon Season (Kharif)		Winter Season (Rabi)	
S. No.	2000–2001	2011–2012	2000–2001	2011–2012
1	Rice	Rice	Wheat	Wheat
2	Cauliflower	Cauliflower	Barseem	Barseem
3	Bajra	Bajra	Mustard	Mustard
4	Calabash	Calabash	Brinjal	Brinjal
5	Gwar	Gwar	Carrot	Carrot
6	Carrot	Carrot	Cauliflower	Cauliflower
7	Arhar	Arhar	Tomato	Tomato
8	Spinach	Spinach	Pea	Pea
9	Ladyfinger	Ladyfinger	Potato	Potato
10	Onion	Onion	Spinach	Spinach
11	Brinjal	Brinjal	Coriander	Coriander
12	Chilly	Chilly	Radish	Radish
13	Cucumber	Cucumber	Calash	Calash
14	Tomato	Tomato	Chilly	Chilly
15	Sugarcane	Sugarcane	Cucumber	Cucumber
16	Fenugreek	Fenugreek	Turnip	Turnip
17	Sweet Potato	Sweet Potato	Fenugreek	Fenugreek
18	Coriander	Coriander	Garlic	Garlic
19	Dhaincha	Dhaincha	Mushroom	Mushroom
20	Potato	Potato	Onion	Onion
21	Water chestnut	Water chestnut	Javi	Javi
22	Cotton	Cotton	Barley	Barley
23	Ridge Gourd	Ridge Gourd	Gram	Gram
24	Moong	Moong	Mash	Mash
25	Sesame seed	Sesame seed	Mustard	Mustard
				Lost species
26	Maize	Maize	Mint	Mint
27	Urad	Urad	Pumpkin	Pumpkin
28	Lobiya	Lobiya	Turmeric	Turmeric
29	Radish	Radish	Colocasia roots	Colocasia roots
30	Jowar	Jowar		
31	Turnip	Turnip		
32	Khair	Khair		
		Lost species		
33	Colocasia roots	Colocasia roots		
34	Bitter Gourd	Bitter Gourd		
35	Garlic	Garlic		
36	Turmeric	Turmeric		
37	Gachak Dana	Gachak Dana		
38	Senat seed	Senat seed		
39	Ash Gourd	Ash Gourd		

as marketing decisions (Bryant et al. 1992). The Government took initiatives to diversify the farmers towards other crop species. Training is being given to them, but it did not work up to a desirable level because the farmers' decision is perhaps determined by market forces. These programs failed to bring desirable changes on the farms.

7.6 Conclusions

This paper attempted to look at the land use changes on the farm in inter-specific crop diversity in the Panipat district of Haryana state in India. It is clear from the data that cereal crops has emerged as dominant crops on the farm followed by fodder crops, cash crops, vegetables and pulses. The percent of the cropped area increased under rice and wheat. Thus, rice and wheat are prominent crops of the cropping system during monsoon and winter respectively and other crop species were no longer farmers' attraction. Hence, the agricultural system is being intensified by rice wheat cropping system. Consequently, monoculture cropping system has emerged. Increase in Irrigation facilities, improved seed varieties, pesticides, insecticides and new methods of farming are found responsible for the changes. Value of productivity and profitability of crops have been discovered to be the most important.

The Harfindahl Index during monsoon and winter season indicates the increase in value from 0.22 (1950–1951) to 0.75 (2011–2012) and from 0.45 (1950–1951) and 0.91 (2011–2012) respectively. It showed the highest concentration of fewer crop species on the farms. Likewise a Simpson index value varies between 0.78 (1950–1951) to 0.25 (2011–2012) and between 0.55 (1950–1951) and 0.09 (2011–2012) during the monsoon and winter season respectively. It shows the region is less diverse in species. Number of crops species in monsoon season decreased from 39 (2000–2001) to 32 (2011–2012) and in the winter season from 29 (2000–2001) to 25 (2011–2012). Therefore, it is necessary for sustaining key functions of the agro-ecosystem including structure and processes for and in support of food production and food security. Its utility signifies its importance for the large population. Crop diversity richness and evenness are really the requirement of sustainable agriculture development. Many farmers rely on a variety of crops which help them maintain their livelihood in the face of uncertain rainfall and fluctuation in the price of cash crops, socio political disruption and the unpredictable availability of agro chemicals. Now in the fastest growing population, crop diversity is considered a need for food security. Despite government's initiatives, rice wheat cropping system prevailed on the farms. There is a need of strong measures otherwise serious environmental problems in agro-ecosystem would occur.

Loss of crop diversity in general would perhaps be solved through adopting some of the solutions viz.

1. Farmers should be encouraged towards diversification of crops for increasing the Crop Diversity,
2. There is a need of strong Information Communication System (ICS) between farmers and policy implementations' officers to flow updated information about the availability of new varieties, market, Government schemes, etc.,
3. Initiatives should be taken for on management (in situ conservation) of farm land by improving the soil fertility.
4. There is a need for agricultural innovation to innovate the farmers to move forward to experiment with a new crop variety on their farms.
5. There is a need to offer alternatives for earning livelihood as agriculture is the backbone of the district economy and farmers' choice of crop species is also influenced by profitability.

According to Food and Agricultural Organization (2009), crop diversity is critical for meeting the food challenges we face right away and evermore. The judicious use and management of crop diversity are perhaps one of the best ways to ensure our ability to use agriculture to sustain, and even improve, our lives and those of our children.

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