2 Cereal-Legume Cropping System in Indian Himalayan Region for Food and Environmental Sustainability

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Abstract

The Indian Himalayan Region (IHR) is extended from Jammu and Kashmir to the northeastern part of the country and shows a great differentiation in climatic, edaphic, geological, vegetation, and other features due to complex variegation of agroecosystems which leads to diverse agroecological zones. Agriculture is the important source of livelihood of the region, and rice (*Oryza sativa* L), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.) are the main crops of the entire IHR. Unsustainable agricultural practices, such as monocropping, conventional tillage, indiscriminate use of fertilizers and pesticides, etc., apart from land degradation and cropland scarcity have serious implications for livelihood security in IHR. Under such scenario, there is a need to diversify cropping pattern to make the entire agricultural system sustainable and environmentally secure. Inclusions of legumes in cereal-based cropping system either as intercrop or in sequence of crop rotation are the most promising options for diversified sustainability of the system and enhance the cropping intensity. Diverse habitat of IHR favors the growth and development of an amazing variety of legumes and other crops which make this region the rich hub for agricultural crop diversity specifically the legume crops. Broad bean (*Vicia faba*), horse gram (*Macrotyloma uniflorum*), field pea (*Pisum sativum*), black gram (*Vigna mungo*), adzuki bean (*Vigna angularis*), cowpea (*Vigna unguiculata*), soybean (*Glycine max*), lentil (*Lens esculenta*), green gram (*Vigna radiata*), beans (*Phaseolus* sp.), lathyrus (*Lathyrus sativus*), pigeon pea (*Cajanus cajan* L), etc. are some of the legumes cultivated by the farming communities in IHR. Rice bean [*Vigna umbellata* (Thunb.) Ohwi and Ohashi and mucuna/velvet bean [*Mucuna pruriens* (L.) DC.] are some of the specific legumes grown abundantly in the eastern IHR which has immense food and natural resource conservation values. Albeit the legume species provides food, fuel, fodder, etc. and has multifarious roles in agriculture and natural resource conservation, their ability to fix atmospheric nitrogen in root nodules and subsequently contributions to the soil fertility give them the unique identity. Legume-based systems improve several aspects of soil fertility, such as soil organic carbon (SOC) and humus content and nitrogen and phosphorus availability, suppress weed growth through smothering effects, increase production per unit area, enhance land use efficiency, reduce runoff and soil loss, etc.

Inclusion of legume provides sustainability to nonlegume cereal component by enriching soil fertility and increasing system productivity and returns. Significant reductions in the release of greenhouse gases, viz., carbon di-oxide, nitrous oxide etc., are a logical consequence of reduced fertilizer and energy use in arable systems with legumes. Pulses are considered the key crops for intensification of rice and maize-fallows of IHR due to their short-duration, hardy, and low-input requiring nature, hence offers a tremendous opportunity to utilize residual soil moisture.

Keywords
Cereal · Cropping system · Indian Himalayan Region · Legume · Land degradation · Sustainability

Abbreviations

B:C	Benefit/cost
BNF	Biological nitrogen fixation
CA	Conservation agriculture
CI	Cropping intensity
CO_2	Carbon dioxide
CT	Conventional tillage
DHA	Dehydrogenase activity
FP	Farmers' practice
EHR	Eastern Himalayan region
IHR	Indian Himalayan Region
LER	Land equivalent ratio
LUE	Land use efficiency
MEY	Maize equivalent yield
mt	Million tons
MT	Minimum tillage
N_2O	Nitrous oxide
NER	North East Region
NT	No-till
PEM	Protein-energy-malnutrition
RDA	Recommended dietary allowances
SMBC	Soil microbial biomass carbon
SOC	Soil organic carbon
SOM	Soil organic matter
USD	US dollar
WUE	Water use efficiency

2.1 Introduction

The Indian Himalayan Region (IHR) with width of 250–300 km across stretches over 2500 km beginning from Arunachal Pradesh in the east to Jammu and Kashmir in the west and spreads between 21°57′–37°5′ N latitudes and 72°40′–97°25′ E longitudes (Bhatt et al. 1999). This great chain of mountains in Indian territory extends all along the northern border of the country which extends from the eastern border of Pakistan in the west to the western border of Myanmar in the east covering partially/fully 12 states of India, viz., Jammu and Kashmir, Himachal Pradesh, Uttaranchal, and Sivaliks of Punjab and Haryana in the west, West Bengal in the east, and Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, and hills of Assam in the northeast (Samal et al. 2005). In continuation of various mountainous countries, the IHR is differentiated by their climatic, edaphic, geological characters, vegetation, cropping patterns, crop rotations, and other features due to complex variegation of agroecosystems. It resulted in representation of diverse agroecological zones in the Himalayas which provides the myriad microhabitats. This diverse habitat favors the growth and development of an amazing variety of legumes and other crops over thousands of years by the hill farmers which make this region the rich hub for agricultural crop diversity specifically the legume crops. The hill and mountain areas of the Himalayas are ecologically fragile and economically not developed well with several problems imposing severe limitations on resource productivity level (Bhatta and Vetaas 2016). Moreover, agriculture is mostly subsistence in nature and is the important source of livelihood of the region. Unsustainable agricultural practices, land degradation, and cropland scarcity have serious implications for food security and Himalayan livelihoods (Partap 1999; Das et al. 2014a Meena et al. 2017a). Crisis area studies, conducted by the Mountain Farming Systems Programme of International Centre for Integrated Mountain Development (ICMOD), documented evidences of unsustainable mountain agriculture in IHR (Shrestha 1992; Pandey 1992; Jodha and Shrestha 1994). Many of the indicators used to illustrate this are derived from the farmers' responses to the lack of adequate cropland management. For example, marginal rainfed croplands in some areas are abandoned because farmers do not perceive that the benefits of cultivation outweigh the costs involved (Partap 1999).

The North East Region (NER) of India also called as the Eastern Himalayan region (EHR) comprises of eight states, namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, and covers about 8.3% geographical area and has about 4% populations of the country (Ngachan et al. 2010). Out of the total 26.27 m ha geographical area of NER of India, around 77% is hills and senile plateau, while only 12% net area is under cultivation (Das et al. 2016). Rainfed, monocropping, and subsistence-type agriculture are the characteristic features of NER. Paddy is grown as the major crop of the region followed by maize. Food crops account for more than 80% of the gross cropped area, and cereals occupy about 70% of that (Gupta et al. 1998). Crop diversification by involving legumes is the need of the hour for the development of sustainable farming systems in this region. Inclusion of legumes in cropping system either as intercrop or in sequence of crop rotation is one of the most promising options for diversified sustainability of the system (Saha et al. 2011; Meena et al. 2015a), and it will create an opportunity to enhance the cropping intensity (CI) manifolds. Out of 23.1 m ha area under pulses in the country, the NER has only 255.99 thousand ha (1.1%). This region contributes only 216.6 thousand tons (1.3%) to the country's total pulse production (2014–2015) of 17.2 million tons (mt). With this production level, the per capita pulse availability in NER is hardly 12.5 g against 46 g at national level. Considering the recommended per capita dietary pulse intake of 50 g, the pulse production in this region needs to be increased by almost four times to make this region self-sufficient in pulses (Das et al. 2016). The fact that the productivity of the pulses in NER (848 kg/ha) is higher than that of country's (743 kg/ha) suggests that this region suits well to requirement of pulses production. The NER has a much wider spectrum of pulses grown than any other regions of the world, and these include pigeon pea [*Cajanus cajan* (L.) Millsp.], pea (*Pisum sativum* L.), rice bean (*Vigna umbellata* Thunb), French bean/rajmash (*Phaseolus vulgaris* L), soybean (*Glycine max*), green gram (*Vigna radiata* L), black gram (*Vigna mungo* L), lentil (*Lens culinaris* Medik), broad bean (*Vicia faba* L), lablab bean [*Lablab purpureus* (L.)], and cowpea [*Vigna unguiculata* (L.) Walp]. Rice bean (*Vigna umbellata*), a highly photosensitive short-day plant, is a very important rainy (*kharif*) season pulse of this region and is an integral component of *jhum*. Recently, identified photo-insensitive genotypes of rice bean have offered prospects of cultivation of this crop in spring/summer season also.

There are many species and varieties of legumes that are cultivated by the farming communities of IHR like broad bean, horse gram (*Macrotyloma uniflorum*), field pea, black gram, adzuki bean (*Vigna angularis*), cowpea, soybean, lentil), green gram, rice bean, etc. Besides, several species and varieties of beans (*Phaseolus* sp.) are exclusive to higher Himalayas. Legume crops are of multipurpose in value and play significant role in providing agricultural, food, nutritional, and livelihood security to the hill farmers. They have been closely interlinked with cereals in a way that in agriculture legumes complement cereals in terms of cropping pattern and crop cycle (Ram and Meena 2014) and provide rich protein and a variety of minerals and nutrients to a cereal-based diet (FAO 1982). Pulses are described as "poor men's meat" (FAO 1982), due to its high protein content. The significance of legume species is not limited only to the use as fuel, fodder, etc. but extended to traditional rituals and ceremonies also. Cultivation of pulses are also an effective means of rehabilitating degraded soils and can contribute significantly to achieving the twin objectives of increasing productivity as well as improving the sustainability of cereal-based cropping systems (Yadav et al. 1998). Naturally the atmospheric nitrogen (N) fixation ability of legumes enriches the soil with available N and not only meets the N requirement of associated crop but also the subsequent crops (Dhakal et al. 2016) and further reduces the use of synthetic fertilizer and organic manures in agriculture. The latter though have been traditionally used in hill agroecosystem and are less available due to dwindling forest cover and decrease in domesticated animal population (Semwal and Maikhuri 1996). Increase in yield of subsequent crops raised after pulses to the tune of about 20–40% has been reported (Joshi 1998). The importance of legumes is much more vital in degraded hill and mountain ecosystem of IHR either in the form of N contribution or through leaf fall. It has been estimated that pigeon pea, soybean, cowpea, groundnut (*Glycine max*), field pea, and rice bean can produce 2.0, 1.2, 2.0, 0.5, 0.48, and 1.1 Mg/ha of leaf fall, respectively, which directly contributes to soil fertility and helps to ameliorate soil acidity (Hazarika et al. 2006). Pulse crops by virtue of their inherent capacity to add N to the soil and recharging of soil micronutrients through its taproot system are the crop of choice for organic production system in the IHR specially NER. Most of the indigenous legumes of the Himalayas have high ecological and economic potential and grow well in harsh environmental conditions (rainfed, low temperature, low fertility, moisture stress, etc.) with little external inputs (Maikhuri et al. 1996). Of late, a decline in interest of hill and mountain farmers toward traditional/indigenous legume crop has been observed as a result of climatic, cultural, and socioeconomic changes. This decline is considered as a big challenge to the indigenous legume crops and their wild relatives, and consequently the subsistence farming system of the region is under threat for sustenance.

2.2 Pulse Scenario in India

India is the largest producer and consumer of pulses in the world accounting for about 29% of the world area and 19% of the world's production (Singh et al. 2015). Ironically, the country's pulse production has been hovering around 14–15 million toones (mt), coming from a near-stagnated area of 22–23 m ha, since 1990–1991 (Singh et al. 2013). The pulse area, production, and productivity increased by 21, 104, and 68% in 2014–2015 as compared to 1950–1951 (Fig. 2.1) (Tiwari and Shivhare 2016). However, record pulse production of 22 mt was achieved in India during 2016–2017. This was mainly due to special emphasis on pulses by providing minimum support price, making available critical inputs to farmers along with large-scale awareness and demonstrations across the country. The low productivity in pulses may be attributed to cultivation under nutrient- and moisture-starved

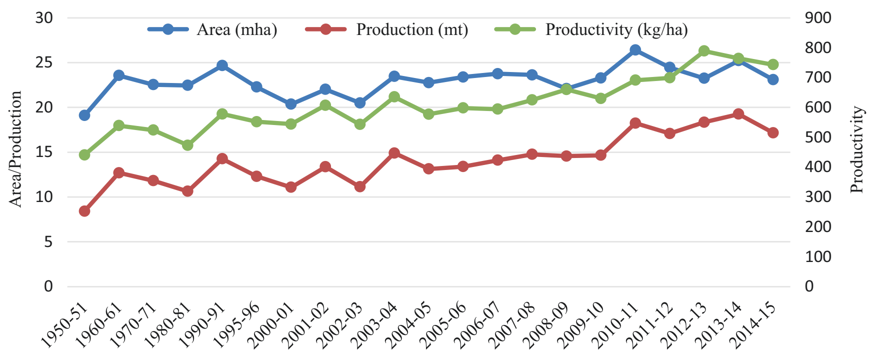


Fig. 2.1 Trends in area, production, and productivity of total pulses in India

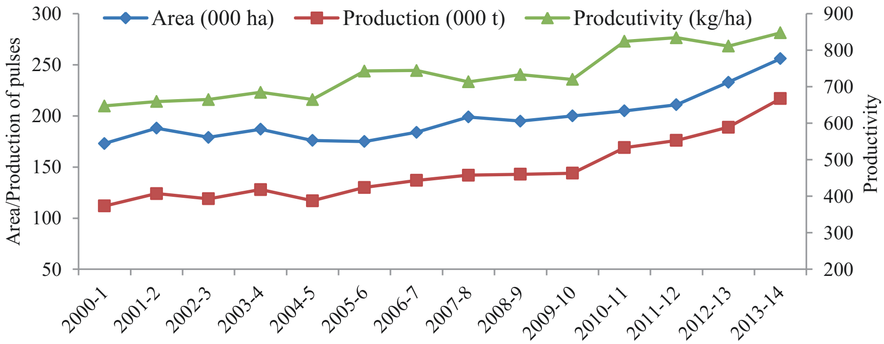


Fig. 2.2 Trends in area, production, and productivity of total pulses in NER (eastern Himalayas)

conditions, priority to cereals and cash crops, non-availability of location-specific pest and disease-resistant varieties, and lack of organized marketing infrastructure (Meena et al. 2015a).

2.2.1 Pulse Scenario in Eastern, Western, and Central Himalayas

The area under pulse crops increased sharply in the NER from 112 thousand ha in 2000–2001 to about 217 thousand ha in 2013–2014 (Fig. 2.2). The productivity of pulses during this period also enhanced from 647 to 848 hg/ha. Assam has the highest pulse area of 149.00 thousand hectares and contributed 104.00 thousand tons of pulse production during 2013–2014, followed by Nagaland and Manipur which accounted 37.80 and 30.38 thousand hectares area and contributed 42.5 and 28.65 thousand tons production, respectively (Das et al. 2016). Among the western and central Himalayan states, during 2014–2015, maximum area and production of pulses are in Uttar Pradesh, while the highest productivity of 1252 kg/ha is found in Himachal Pradesh which is 68% higher than the national average (743 kg/ha), and the lowest productivity is of Jammu and Kashmir (292 kg/ha, 61% lower than the national average) (Fig. 2.3) (Tiwari and Shivhare 2016).

2.2.2 Major Pulses of IHR

The major pulses grown in IHR are green gram, black gram, pigeon pea, rice bean, cowpea, etc. in *kharif* and French bean, chickpea (*Cicer arietinum*), lentil, khesari (*Lathyrus sativus*), and field pea in *rabi* season. In hills, various other beans such as faba bean/broad bean, adzuki bean, moth bean (*V. aconitifolia*), and lablab bean or *sem* are also grown as pulse. In *jhum* areas of the NER, rice bean is still a predominant pulse crop. Important pulses grown in IHR along with their growing season and major uses are presented in Tables 2.1 and 2.2.

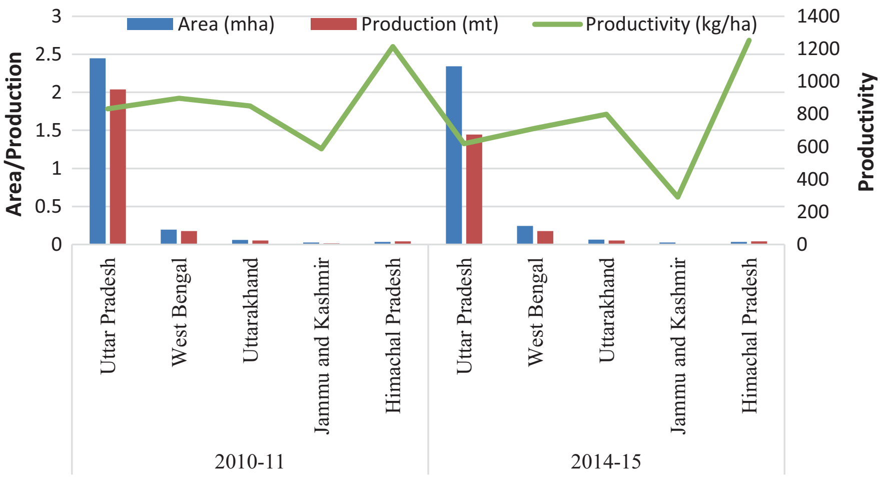


Fig. 2.3 Trends in area, production, and productivity of total pulses in western and central Himalayan states

Table 2.1 Pulse/grain legumes grown in Eastern Himalayan region

Botanical name	Local name	Growth period	Uses
Cajanus cajan	Arhar	June–Dec	Cooked as "dal," consumed during jaundice, dried stem used as fuel
Cicer arietinum	Chana	Oct–Feb	Cooked as "dal," whole plant as vegetable, and sprouted seeds consumed raw
Lathyrus sativus	*Soshta batura* (white seeded)	Oct–Feb	Highly nutritious, consumed with vegetables or with chana dal, always taken as mixed legume diet, tender pods and leaves as vegetables, rough "chapatti," whole plant used as fodder, manure
	Kalo Batura (black seeded)	Sep–Feb	
	Pahelo batura (brown mottled), khesari		
Lens esculenta	Masoor	Oct–Feb	Cooked as a dal, light meal taken during severe jaundice, indigestion, and loss of appetite
Macrotyloma uniflorum	Gahat	June–Sep	Consume to withstand extreme cold, lowering high cholesterol
		July–Oct	
Phaseolus lunatus	*Lachen tibi, Singtamey simi, Ghew bori*	Aug–Oct	Sprouted seed used as a breakfast, dal, tender pod as a vegetable
Phaseolus vulgaris	Kalo Mantulal simi/Alpatre simi/Harey simi	July–Nov	Sprouted seed used as a breakfast, dal, tender pod as a vegetable

(continued)

Table 2.1 (continued)

Botanical name	Local name	Growth period	Uses
Pisum sativum	Matar/Kerau	Oct–Feb	Cooked as "dal" or as mixed vegetable of tender pods, seeds, and leaves
Vicia faba	Bakulla	Oct–Jan	Young pods as vegetable. Dried bean fried, roasted, or mixed with pea, gram, mung, germinated to form soup, eaten with rice
Vigna mungo sp. niger	Kalo dal (black seeded)	Aug–Nov	Medicinal (at constipation, weakness), cooked as pulse meal or "dal" or mixed with radish, cabbage, salt, and lettuce leaves
Vigna mungo sp. viridis	*Pahenlo dal* (green seeded)	Aug–Nov	Cooked as dal and as a medicine (for low blood pressure)
Vigna radiata	*Mung dal*	Aug–Nov	Cooked dal
Vigna umbellata	Rato maysum dal (red-seeded)	July–Oct	As a dal, raw plants or tender pods. Seed flour mixed with paddy straw and water to form feed meal
	Kalo maysum dal (black-seeded)	July–Oct	As a dal, whole plant as energetic cattle feed
	Seto maysum dal (white-seeded)	July–Oct	Dry seed or cooked, mixed and boiled with pea and urd. Tender pods with young seed consumed for lowering cholesterol
	Tulo maysum dal	Aug–Nov	Mixed with chana and pea, palak, carrot, cooked as mixed eaten during extreme cold fever
Vigna unguiculata	Tuney bori	July–Oct	Grains are cooked or mixed with local herbs. Whole plant used as mulch or cover crops, also consumed during cold fever
Vigna sinensis	Thangre	July–Oct	Fodder/green manuring

Source: Das et al. (2016)

Table 2.2 Pulse/grain legumes grown in central and western Himalayan states

State	Pulse/grain legume
Jammu and Kashmir	Field pea (*Pisum sativum*), chickpea (*Cicer arietinum*), lentil, horse gram (*Macrotyloma uniflorum*), *Phaseolus* sp., etc.
Himachal Pradesh	Urd bean (*Vigna mungo*), lentil (*Lens esculenta*), field pea (*Pisum sativum*), horse gram (*Macrotyloma uniflorum*), rice bean (*Vigna umbellate*), etc.
Uttar Pradesh	Chickpea (*Cicer arietinum)*, lentil (*Lens esculenta*), field pea (*Pisum sativum*), pigeon pea (*Cajanus cajan*), urd bean (*Vigna mungo*), mung bean (*Vigna radiate)*, broad bean (*Vicia faba*) (grown sporadically), etc.
Uttarakhand	Mung bean (*Vigna radiate)*, urd bean (*Vigna mungo*), lentil (*Lens esculenta*), horse gram (*Macrotyloma uniflorum*), chickpea (*Cicer arietinum*), rice bean (*Vigna umbellate*), etc.

Table 2.3 Biochemical constituents of some indigenous legumes of Eastern Himalaya

Legume	Biochemical constituents	References
Broad bean	Starch (62–65.3%), protein (20–25%), dietary fiber (20.4–26.8%),	Sharma et al. (2003)
Winged bean	Protein (40–50%)	Sharma et al. (2003)
Jack bean	Protein (23%- 34%), carbohydrate (55%), crude fiber (2.55 ± 0.15%), ash content (3.45 ± 0.96%)	Akpapunam and Sefa-Dedeh (1997); Abitogun and Olasehinde (2012)
Rice bean	Carbohydrate (58.2–72.0%), crude protein (18.3–32.2%), ash (3.5–4.9%), soluble ether extract (0.1–0.5%), crude fiber (3.6–5.5%)	Buergelt et al. (2009)
Pigeon pea	Protein (21.0%), starch (48.4%), soluble sugar (5.1%), crude fiber (8.2%), fat (2.3%) in green seed Protein (18.8%), starch (53.0%), soluble sugar (3.1%), crude fiber (6.6%), fat (1.9%) in mature seed.	Saxena et al. (2010)
French bean	Carbohydrate (59.12%), protein (22.1%)	Ganie et al. (2014)
Cowpea	Carbohydrate (56–66%), protein (22–24%), crude fiber (5.9–7.3%), ash (3.4–3.9%), fat (1.3–1.5%)	Gómez (2004)
Peas	Carbohydrate (61.55%), protein (21.87%), fiber (1.47%), oil (1.58%), ash (2.70%)	Mishra et al. (2010)

2.2.2.1 Indigenous Pulses of EHR

There are some unique pulses grown in the EHR from time immemorial due to their ability to adapt in diverse agroclimatic conditions of the region. Some of the indigenous legumes are adzuki bean), broad bean, moth bean, local khesari, winged bean (*Psophocarpus tetragonolobus*), tree beans (*Parkia roxburghii*), jack bean (*Canavalia ensiformis*), sword bean (*Canavalia gladiata*), etc. *Vigna vexillata* is another less known potential pulse cum tuber crop of this region resembling cowpea and produces both edible seeds and tubers. Bakthul bean (*Sesbania grandiflora*) is also an indigenous, underutilized potential leguminous crop generally grown in NER (Das and Ghosh 2012). Indigenous legumes are superior in nutritional value over many of the more commonly grown pulses (Table 2.3). Rice bean is grown predominantly under the rainfed conditions in a mixed farming system under the shifting cultivation or in kitchen gardens (Yadav et al. 2017a, b). It is a multipurpose legume which can be used as food, fodder, green manure, cover crop, etc. In view of enormous variability, high yield (1.5–2.0 Mg/ha), tolerance to disease and pest, and wider adaptability, this underexploited legume grown predominantly in mixed farming system has great potential to become an important pulse crop of the region. Due to high content of L-dopa, broad bean can potentially be included in dietary strategies to manage Parkinson’s disease (Kempster et al. 1993). Winged bean is also an important pulse crop of the region used both as pulse and vegetables as a favorite supplementary delicacy. Winged bean has very high contents of crude fat (1.7%), protein (50.7%), potassium (8.9 mg/g), calcium (8.06 mg/g), and magnesium (5.72 mg/g) in full mature seed and high total soluble sugar (488.80 mg/g), nonreducing sugar (415.95 mg/g), and starch (420.60 mg/g) in tuber (Ningombam et al. 2012). Mucuna/velvet bean [*Mucuna pruriens* (L.) DC.] is an important pulse crop of the IHR having medicinal potential and plays a significant role in soil conservation (Kala, 2005).

Pahenlo dal (unique green-seeded urd bean) is one of the most extensively grown pulses in Sikkim as *kharif*/pre-*rabi* crop. Local collections of *Pahenlo dal* are semi spreading types, and pods are less hairy than black-seeded urd bean. *Pahenlo dal* possesses higher amount of protein as compared to *Kalo dal* (black-seeded urd beans) and better in taste. The seeds of *Pahenlo dal* are thin and longer than the *Kalo dal*. SKMPD-3 is most promising variety of *Pahenlo dal* developed by ICAR Research Complex for NEH Region, Sikkim Centre, Sikkim through local selections. *Kholar bean* (a variant of rajmash) is very popular in Nagaland and mostly cultivated in *jhum* fields.

2.2.3 Cropping System in Central Himalayas

Crops and cropping systems in the central Himalayas are diverse due to large agroecological and cultural diversity, which has led to variable cropping patterns. About 80% of people of the central Himalayas practice subsistence agriculture (Maikhuri et al. 2001). Land holdings are small, with fragmented and terraced slopes covering 85% of total agricultural land which is rainfed, while the valley area, which covers 15% of agricultural land, is irrigated. In the central Himalayas, intercrop combinations traditionally involve cereals with millet, millet with legumes, and legumes with legumes. Intercropping finger millet (non-legume) with legumes often results in higher resource use efficiency compared to sole cropping (Chandra 2007; Ram and Meena 2014). The intercropping species that differ in sowing and harvesting times, and their maximum demands on environmental resources, extends the duration of resource use (Chandra et al. 2011b). Finger millet (*Eleusine coracana*) is known for its high mineral contents (Chethan and Malleshi 2007), and legumes fix nitrogen symbiotically. Such complementarities between crops in resource use are particularly important in low input subsistence farming systems such as those in the central Himalayas. Finger millet and black gram are commonly intercropped, and these species are the most important staple food crops in the Garhwal area of the central Himalaya.

2.3 Prospect of Legumes in IHR

Farmers and people of mountain ecosystem of IHR are resource poor and reside in ecologically sensitive region. Land degradation, low productivity, poor nutrition and health, low income, and vulnerability to climatic variabilities and extremes are some of the features of the Himalayan ecosystem (Meena et al. 2017a). Thus, inclusion of food legumes in production systems can play multiple roles and services at

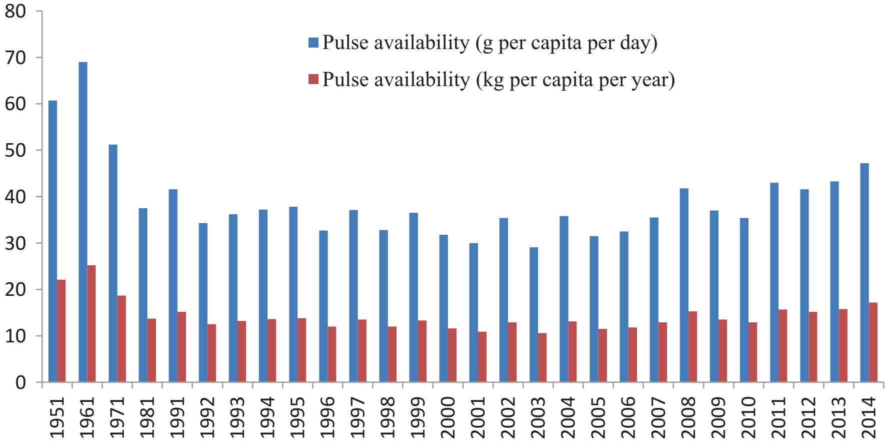


Fig. 2.4 Per capita availability of pulses in India. (*Source*: Agricultural Statistics at a glance-2014)

food system level, both for human and animal consumption, as a source of plant proteins (Tharanathan and Mahadevamma 2003); at production system level, through atmospheric N fixation and due to their ability in mitigating greenhouse gases emissions (Lemke et al. 2007; Meena et al. 2015b); and at cropping system levels, through crop diversification breaking the cycles of pests and diseases and contributing to balance the deficit in plant protein production (Peoples et al. 2009).

The recommended dietary allowances (RDA) of pulses for adult male and female are 60 g and 55 g per day against availability of 46 g/day in 2016 (Fig. 2.4). The per capita availability is much lower in IHR. The deficiency of protein in human diet often leads to protein-energy malnutrition (PEM) causing various forms of anemia. Legumes are a significant source of protein, dietary fiber, carbohydrates, vitamins, and dietary minerals. 100 g legumes provide energy 321–570 Kcal, protein 21–28 g, fat 0.8–48.0 g, carbohydrate 21–63.4 g, and total dietary fiber 9.0–22.7 g. Lentil is very rich in pantothenic acid (2.12 mg/100 g), vitamin B_6 (0.54 mg/100 g), folate (479 mg/100 g), etc. Cowpea is also rich in vitamin B_6 (0.44 mg/100 g), folate (546 mg/100 g), etc., and vitamin C content of soybean is highest (6 mg/100 g) among pulses (Table 2.4).

2.4 Land Degradation in IHR

Land serves as the storage bin for water and nutrients required for growth and development of different crops. Soil degradation is a great challenge in India specially in IHR with respect to food and environmental security. According to the NBSS&LUP (2004), out of the total geographical area of 328.37 m ha of India, approximately 146.8 m ha (44.7%) is under various kinds of degradation. Out of the total degraded area of the country, ~ 42.9 m ha (29.22%) is in IHR (Table 2.5). Degradation due to water erosion is the most serious problem in India, leading to loss of top fertile soil

Table 2.4 Nutritive value of some important legumes (per 100 g) of IHR

Pulses	Energy (Kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Total dietary fiber (%)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Iron (mg)	Zinc (mg)	Calcium (mg)
Chickpea	368	21.0	5.7	61.0	22.7	0.30	0.51	1.5	6.2	3.4	105
Pigeon pea	342	21.7	1.49	62.0	15.5	0.45	0.51	2.9	5.2	2.7	130
Urd bean	347	24.0	1.6	63.4	16.2	0.41	0.37	2.3	8.4	3.5	110
Mung bean	345	25.0	1.1	62.6	16.3	0.72	0.15	2.3	6.7	2.7	132
Lentil	346	27.2	1.0	60.0	11.5	0.45	0.49	2.6	7.5	4.7	56.0
Field pea	345	25.1	0.8	61.8	13.4	0.47	0.21	2.9	4.4	3.0	55.0
Rajmash	345	23.0	1.3	63.4	18.2	0.53	0.22	2.08	3.4	1.9	186
Cowpea	346	28.0	1.3	63.4	18.2	0.50	0.48	2.36	7.5	3.7	80.3
Horse gram	321	23.0	2.3	59.1	15.0	0.42	0.20	1.5	7.0	–	287
Moth bean	330	24.0	1.5	61.9	–	0.45	0.09	1.5	9.6	–	202
Peanut	570	25.0	48.0	21.0	9.0	0.60	0.30	12.9	2.0	3.3	62.0
Soybean	446	16.49	19.9	30.1	9.3	0.87	0.87	1.62	15.7	4.9	277
Khesari						0.39	0.41				

Source: *The Nutritive value of Indian Foods & the planning satisfactory Diets (ICMR)*; http://www.iipr.res.in/pdf/15.1_270615.pdf

Table 2.5 Extent of land degradation in IHR

State	Total degraded area (m ha)	% of degraded area to total ground area of the state
Manipur	1.9	42.6
Mizoram	1.9	89.2
Meghalaya	1.2	53.9
Assam	2.2	28.2
Arunachal Pradesh	4.6	53.8
Nagaland	1.0	60
Sikkim	0.2	33
Tripura	0.6	59.9
Himachal Pradesh	4.2	75
Jammu and Kashmir	7	31.6
Uttar Pradesh + Uttarakhand	15.3	52
West Bengal	2.8	31
Total	42.9	–

Source: NBSS & LUP-ICAR (2005) on 1:250,000 scale

and formation of gullies, landslides, and terrain deformation. The average soil erosion rate of India was about 16.4 Mg/ha per year, resulting in an annual total soil loss of 5.3 billion tons (Dhruvanarayan and Ram 1983;; Datta et al. 2017). About 29% of total eroded soil is lost to the sea, 61% eroded soil is translocated from one place to another, and the remaining 10% is deposited in reservoirs leading to imbalance in ecosystem.

India is losing a huge exchequer every year due to soil and land degradation. Costs of inaction on land degradation are higher than the costs of action, indicating the benefits that will accrue if sufficient conservation practices are undertaken. The total annual costs of land degradation by land use and cover change in 2009 as compared to 2001 in India are estimated to be about 5.35 billion USD with an annual per capita cost of 4.4 USD (Indian Ministry of Statistics and Programme Implementation, 2014**)**. The ratio of action over inaction is in the range of 20–40% in humid regions in general and above 40% in subhumid and arid regions (Mythili and Jann Goedecke 2016). Total direct cost of soil degradation was estimated at INR 448.6 billion with cost of soil erosion in lost production at INR 361 USD (Sehgal and Abrol 1994). Annual per capita cost of soil degradation of Himalayan states are much higher than other states (Table 2.6) due to steep topography, high rainfall, cultivation practices, and anthropogenic activities like road constructions, urbanization, etc. Monetary losses amounting to 22% **(***564.64 million USD***)** for pulses due to water erosion have been reported by Sharda et al. (2010).

In NER, *jhum* cultivation (primitive form of slash and burn agriculture) is still practiced in approximately 0.756 million ha land area resulting in burning phytomass (including forest floors) of more than 8.5 mt annually (Choudhury et al. 2015a), and it accounted for 146.6 Mg/ha per year soil loss in the first year *jhum* cultivation, 170.2 Mg/ha/year in second year *jhum* cultivation, and 30.2 Mg/ha per year in

Table 2.6 Annual per capita cost (USD) of soil degradation in Himalayan vs. other states of India

States	Annual per capita cost (USD) of soil degradation
Arunachal Pradesh	76.6
Manipur	47.6
Meghalaya	42.5
Nagaland	46.9
Mizoram	176.1
Sikkim	47.0
Tripura	40.1
Jammu and Kashmir	20.0
Uttarakhand	20.3
Jharkand	6.6
Chhattisgarh	10.0
West Bengal	0.9
Punjab	0.3
Tamil Nadu	3.5
India	4.4

Sources: Indian Ministry of Statistics and Programme Implementation (2014); Mythili and Goedecke (2016)

abandoned *jhum* fallow (Darlong 1996). In case of cultivation in hill areas, it has been seen that soil loss is more in case of *jhumming* in comparison to others. Agricultural activities leading to soil/land degradation are low and imbalanced fertilization, excessive tillage and use of heavy machinery, crop residue burning and inadequate organic matter inputs, poor irrigation and water management, poor crop rotations, pesticide overuse and soil pollution (Verma et al. 2015a, b, c), etc. Apart from faulty agricultural activities that led to soil degradation, other human-induced land degradation activities include overgrazing, deforestation, and careless forest management; urban growth, industrialization, and mining; and natural (earthquakes, tsunamis, droughts landslides, volcanic eruptions, etc.) and social sources (land shortage, decline in per capita land availability, population increase, etc.) of land degradation, etc.

Some of the strategies to mitigate land degradation are soil erosion control measures, rainwater harvesting, terracing, and bio-fencing; cover cropping, agroforestry, grass water ways, intercropping, strip cropping, and contour farming; watershed approach; residue recycling and minimal soil disturbance; integrated nutrient management, application of organic manure, and reclamation of acid soils; vegetative barriers, mulching, and diversified cropping; agroforestry; conservation agriculture (CA); etc. Soil conservation measures, such as contour plowing, bunding, and use of strips and terraces, can decrease erosion and slow runoff water. Pulses are the candidate crop for all the above conservation measures for erosion control, fertility enhancement, and resource conservation (Dhakal et al. 2016). Pulses act as cover crop that reduces the impact of falling raindrops on the soil surface, increases infiltration of water into the soil, reduces runoff velocity resulting in reduction in loss of top soil and nutrients, etc. Intercropping of cowpea with maize (2:1) has been reported to decrease runoff and soil loss by 10% and 28%, respectively, compared to pure maize (Srinivasarao et al. 2014). When cereal crops like maize and sorghum are cultivated along with legumes like green gram (*Vigna radiata* L.), groundnut, black gram (*Vigna mungo* L.), and cowpea (*Vigna unguiculata*) as intercrops, sufficient ground cover is ensured, and hence, there is drastic reduction in erosion hazards (Rao and Khan 2003). Integrated application of NPK mineral fertilizers along with organic manure increases crop productivity, improves soil physical properties and organic carbon (SOC) content, and decreases soil loss by improving soil aggregation(Varma et al. 2017a, b). It has been reported that about 25% and 19% of gross C input contributed to higher SOC concentrations after 9 years of irrigated or after 30 years of rainfed soybean-wheat production, respectively (Kundu et al. 2007, Bhattacharyya et al. 2009). Increase in SOC pool due to restoration of salt-affected soils has been also reported by Bhojvaid and Timmer (1998).

2.5 Role of Legumes in Soil Sustainability

Inclusion of legumes in cereal-based cropping system substantially reduces the use of fertilizers and energy requirement and consequently lowers down the GHG emissions. The role of legumes in climate change mitigation has not been properly addressed. Legumes have the great potential to lower the emission of GHGs such as carbon dioxide (CO_2) and nitrous oxide (N_2O) compared to mineral N fertilization-based conventional agriculture (Reckling et al. 2014). Legumes also play an important role in the carbon sequestration in soils (IPCC 2007; Yadav et al. 2017a) and reduce the fossil energy inputs in the farming system (Jensen et al. 2012). The legume benefits in agronomic terms have been divided into “N effect” and “break crop effect” (Chalk 1998). The “N effect” component is due to N provision from BNF (Peoples et al. 2009). The N effect of legume is generally higher in situations of low N fertilizer application to subsequent crops (Preissel et al. 2015), whereas the benefits of “break crop effect” include improvements in soil properties such as soil organic matter (SOM) and structure (Hernanz et al. 2009), soil aggregation, water retention and available water (Angus et al. 2015), phosphorus (P) mobilization (Shen et al. 2011), reduction in GHG emission (Stagnari et al. 2017; Meena et al. 2017b), and less insect, disease, and weed problems (Robson et al. 2002).

Continuous cultivation along with conventional tillage systems may cause significant SOC losses through decomposition of humus (Christopher and Lal 2007). Shifting from pasture to field crops has been reported to result in loss of soil C stocks between 25% and 43% (Soussana et al. 2004). Inclusion of legumes in cropping/farming systems can improve multiple soil properties, such as SOC and humus content and N and P availability (Jensen et al. 2012). Besides, the

Table 2.7 N economy due to inclusion of pulses in sequential cropping

Preceding legume	Following cereal	Fertilizer N equivalent (kg N/ha)
Chickpea	Maize	60–70
	Pearl millet	40
Pigeon pea	Wheat	40
	Maize	20–49
	Pearl millet	30
Lentil	Pearl millet	40
	Maize	18–30
Peas	Pearl millet	40
	Maize	20–32
Green gram	Pearl millet	30
Lathyrus	Maize	36–48
Cowpea	Pearl millet	60
Pigeon pea	Sorghum	51
Mung bean	Rice	40
Chickpea	Rice	40
Rajmash	Rice	40
Fodder cowpea	Rice	40

Source: Lee and Wani (1989); Hazarika et al. (2006)

pulse and legume crop can fix the atmospheric N in soil and improve the soil health (Singh and Singh 2002), reduce the soil loss, conserve the soil and water, and suppress the weed growth through smothering effects (Konlan et al. 2013). The N economy due to inclusion of pulses in sequential cropping is given below in the Table 2.7.

2.5.1 Legume Effect on Soil Properties

Improvement in soil physicochemical and biological properties due to legume-based systems has been reported by Jensen et al. (2011, 2012). Ngangom et al. (2017a, 2017b) also reported substantial improvement in maize equivalent yield and soil physical, chemical, and biological properties due to inclusion of legumes in maize-based cropping system in Meghalaya plateau of EHR. Due to inclusion of legumes (green gram, French bean), SOC content is enhanced by 5.7–6.9%, available N by 5.6–11.0%, available P by 4.9–27.6%, available K by 10.3–11.2%, soil microbial biomass carbon (SMBC) by 4.7–8.4%, and dehydrogenase activity (DHA) by 11.0–32.3% as compared to maize-fallow. They also observed improvement in soil moisture stock and water holding capacity due to inclusion of pulses in the maize-based cropping system (Table 2.8; Fig. 2.5). Legumes can increase SOC content in several ways, by supplying biomass, organic C, and N to soil (Lemke et al. 2007; Meena et al. 2017c), as well as releasing hydrogen gas as by-product of BNF, that promote nodule development in the rhizosphere (La Favre and Focht 1983). Legumes also promote SOC content through breakdown of its residues

Table 2.8 Effect of cropping systems on maize equivalent yield (MEY), soil physical, chemical and biological properties after harvesting of winter crops

Cropping system	MEY (Mg/ha)	Bulk density (Mg/ m^3)	SOC (%)	Available nutrients (kg/ha)			SMBC (µg/g soil)	DHA (µgTPF/ hr./g)
				N	**P**	**K**		
Maize-fallow	3.12	1.28	1.59	242.0	12.3	249.7	238.5	28.2
Maize-French bean (bunch type)	7.02	1.28	1.68	259.9	12.9	275.5	249.8	32.0
Maize-French bean (pole type)	8.39	1.27	1.72	255.5	12.0	277.6	258.6	37.3
Maize-black gram	6.55	1.24	1.70	268.6	15.7	248.4	255.8	31.3

Source: Ngangom et al. (2017a)

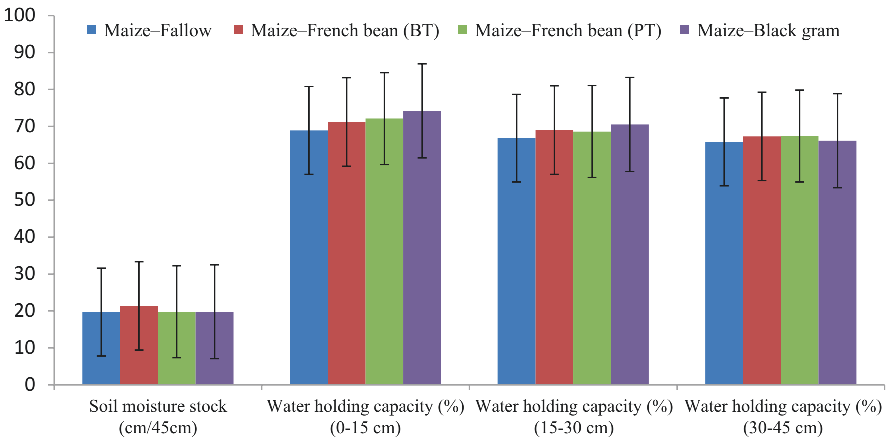


Fig. 2.5 Soil moisture stock and water holding capacity as affected by inclusion of pulses in maize-based system (Ngangom et al. 2017b)

(Köpke and Nemecek 2010; Alpmann et al. 2013). Minimun/no-till along with residue retention has been reported to reduce production costs substantially when combined with the diversification of the crop rotation by including a legume. Cost savings up to 21% has been reported when switched over from a conventional tillage, cereal-based rotation to a conservation tillage-based rotation involving legumes, compared to a cost savings of 12.5% only when the tillage system was changed, but the cereal-dominated rotation was maintained (Luetke-Entrup et al. 2003). Inclusion of pea in rotation with cereal exerted the most positive action to SOC content relative to other legumes (Hajduk et al. 2015). Legumes can reduce soil compaction by providing a continuous network of residual root channels and macropores in the subsoil, penetrating soil hardpans through its vigorous taproot systems (Jensen and Hauggaard-Nielsen 2003; Peoples et al. 2009). Intercropping of groundnut, French bean, rice bean [*Vigna umbellata* (Thunb.)], and cowpea has been reported to reduce soil loss and enhance soil properties and system productivity compared to monocropping of maize in sloping lands of Umiam, Meghalaya (Rajkhowa et al., 2016). Maize + soybean (2:2)-groundnut (237.6 kg/ha) and maize + soybean – French bean (232.2 kg/ha) had higher soil available N after three cropping cycles than rice + soybean (4:2)- tomato (225.8 kg/ha) and rice + soybean-rapeseed (220.5 kg/ha) in mid hills of EHR (Das et al. 2014a, b).

2.5.2 Efficient Utilization of P

Legumes solubilize soil phosphates through root exudates, and their deep taproot system contributes to efficient recycling and utilization of nutrients (Nuruzzaman et al. 2005, Jensen and Hauggaard- Nielsen 2003; Yadav et al. 2017b). Roots of leguminous crops releases organic acids like carboxylic acids that solubilize phosvthat are generally not available to plants. The release of organic acids depends on the soil pH and P concentrations. More organic acids are generally released when soil P concentration is low, and depending upon species of legumes grown up to eight acids are released through root exudations (Egle et al. 2003). Release of organic acids through root exudations benefits the P uptake by the cereal component in mixture (Li et al. 2007) and also cereals crops grown as succeeding crop after legume crops (Nuruzzaman et al. 2005). Increase in P availability in soil and root rhizosphere due to acidification in maize-cowpea intercropping system than in sole cropping has been reported (Latati et al. 2016).

Significant reductions in GHG emission, viz., CO_2 and N_2O, due to low fertilizer especially N fertilizer and energy use in crop production with legumes have been reported (Jensen et al. 2011). However, CO_2 emissions from roots of legumes having nodules can be higher than those of other crops. This C emission is considered not to impact CO_2 concentrations in the atmosphere since it has been captured through recent photosynthesis (Jensen et al. 2011). Legume crops have the potential to reduce N_2O losses when grown in legume-cereal intercropping systems (Pappa et al. 2011). Furthermore, the inhibiting effect on denitrification in the root zone of some plants by rhizobia and other bacteria can contribute to reduction in N_2O emissions (Henry et al. 2008; Verma et al. 2015a, b, c). N_2O emissions to the atmosphere were also reported to be lower from legume systems than those of N-fertilized nonlegume crops and pastures (Dusenbury et al. 2008; Jensen et al. 2011).

2.6 Scope of Legume in Existing Cropping Systems

Pulses are considered the key crops for intensification of rice-fallows (Ghosh et al. 2016). Pulses being short duration, hardy, and low-input requiring in nature offer a tremendous opportunity to utilize residual soil moisture in rice-fallow (Ghosh et al. 2016). Further, given unique characteristics of biological nitrogen fixation (BNF),

Table 2.9 Cropping system in different Himalayan agroclimatic region

Agroclimatic zones	States represented	Annual rainfall (mm)	Cropping system
Western Himalayan region (dry temperate, terraced farming, low biodiversity)	Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh	1650–2000	Rice-chickpea/lentil/field pea, maize-chickpea/field pea, ragi-chickpea/lentil/field pea, maize-urd bean/mung bean/wheat, pigeon pea-wheat, mung bean/urd bean-mustard, common bean-potato
Central Himalayan region (subtropical in Southern foothills, warm temperate in middle Himalayan valleys, cool temperate in middle Himalayas)	Uttarakhand	490–1570	Rice-pea, sorghum (grain/fodder)-chickpea, fallow-chickpea, sorghum + pigeon pea-fallow, pearl millet + pigeon pea-fallow, rice/maize-chickpea/lentil, moth bean/mung bean/urd bean-wheat, rice/maize-chickpea/lentil/field pea, moth bean/mung bean/urd bean-wheat, pearl millet-chickpea
Eastern Himalayan region (moist subtropical, shifting cultivation, high biodiversity)	Manipur, Meghalaya, Nagaland, Arunachal Pradesh, Sikkim, Tripura, Mizoram, hilly tracts of Assam, West Bengal	1840–3530	Rice-urd bean/mung bean, rice-lathyrus, maize-maize-urd bean, maize-pigeon pea/horse gram, maize-chickpea/lentil/field pea, jute-urd bean-chickpea/lentil, soybean/groundnut-rapeseed/mustard

Source: Singh et al. (2005); Pattanayak and Das (2017)

deep rooted, potential to establish with surface broadcast in standing rice fields and soil fertility restoration property pulses can be best fitted in rice-fallows (Ali et al. 2014). Further, inclusion of pulses in rice-fallows is a low-cost approach that can improve the farm income of the resource poor hill farmers. In spite of a few point of preference over other crops, a number of abiotic factors related to soil and water largely limit the production potential of pulses in rice-fallows. In addition, biotic factors also cause severe loss to the pulse crops in rice-fallows (Bandyopadhyay et al. 2015). Consequently, strategic management options needs to be worked out to cope up with the challenging environments of rice-fallows (Das et al. 2016). Legumes due to their competitive nature and environmental and socioeconomic benefits are suitable for introduction in modern cropping systems to increase crop diversity and reduce use of fertilizer and other external inputs (Stagnari et al. 2017). Cropping systems involving pulses in Himalayan agroclimatic region are given in Table 2.9.

2.6.1 Potential Future Pulse-Based Cropping System for IHR

Most of the IHR states are deficient in food grain production and are expected to increase in deficiency by 2050 due to increasing population growth. The CI of the IHR states is also low. However, some of the states like Tripura have already achieved 186% CI, thus showing the way for the other states to follow. With the inclusion of pulses in the existing system, adequate conservation measures, efficient use of natural resources, improved seeds, planting materials, and policy supports, it is possible to achieve at least 200% CI even under rainfed conditions. When maize is planted by last week of April or first week of May, it is harvested by August, which is the peak period of monsoon in Northeast India. The crops like French bean, black gram, rapeseed, etc. can be cultivated with residual moisture. A profitable crop yield is achieved when timely sowing of *rabi* crops done along with adequate nutrient and pest management is practiced. Similarly, after rice harvest in October for upland and November for lowland, pulses like pea, lentil, and oilseeds like rapeseed can be grown with residual moisture (Das et al. 2016). In case of upland, lifesaving irrigation is required during vegetative and flowering stages. With the change in lifestyle and increase in income, demand for rice will be reduced; instead consumption of pulses, fruits, and vegetables will increase. Thus, diversification of rice- and maize-based cropping system with pulses and vegetables is the need of the hour. Also, many farmers and entrepreneurs are looking for commercial livestock and poultry farming. However, high cost of feed is the limiting factor for promotion of these sectors. Thus, cultivation of food-feed crops for dual purpose should be emphasized. Crops like maize, soybean, sweet potato, colocasia, elephant foot yam, dioscorea, etc. are having high-yield potential and feed value. 300% CI with tomato/potato/French bean in pre-*kharif* (Jan-May), okra in *kharif*, and French bean/rajmash in pre-*rabi* were achieved under raised beds in lowland (Das et al. 2014a; Varma et al. 2017a, b). Similarly, rice-pulses-French bean/buckwheat is possible in lowland with one or two irrigation facilities for pre-*rabi* crops. Among the maize-based cropping systems, maize (green cobs)-groundnut-mustard was the most profitable cropping system producing (11.90 Mg/ha) maize equivalent yield with highest economic return of Rs 13,550/ha under upland conditions in mid-altitudes followed by French bean (green pods)-French bean grain (Munda et al. 1999). When maize is taken as green cob, it can be harvested by the onset of monsoon, and regular rice or maize can be taken during rainy season. After rice/maize, pulses or oilseeds can be cultivated. Year 2015 and then 2016 are reported to be the warmest year in history. The NER also follows almost similar trend. There is widening of gap between day and night temperatures in many places. Rain fall is becoming more erratic and unpredictable with more of extreme events. Droughts and flood are becoming more frequent in the region (Das et al. 2009; Meena et al. 2016). Drought of 2006, 2009, and 2014 and floods of recent past are the major reason for worry to achieve sustainable food production in IHR. Thus, there is need for crop diversification and adoption of a farming system approach, so that in the event of drought or floods some or other components will survive and farmers will continue to get their livelihood support. Inclusion of tree components like leguminous *Parkia roxburghii* in farming system will add to the resilience of the system and assured income. Vertical intensification, terrace farming, kitchen gardening, family farming, hydroponics, aeroponics, etc. are some of the future cropping systems and crop production approaches to adopt climate change and make agriculture a profitable enterprise (Pattanayak and Das 2017).

The fact that NER of India has been identified as hub for organic food production, emphasis has to be given on high-value crops having more market demand. Crop rotations, including a leguminous fertility building crops and cash crops, are the main principles for nutrient management within organic production systems. Organic rotations are divided into phases: one phase improves the level of soil N, and another depletes it. The N building and depleting phases must be in balance, with opportunities for fertility building for long-term sustenance farming (Meena et al. 2015a; Berry et al. 2003). Leguminous cover crops such as soybean, rice bean, velvet bean, etc. are suitable intercrops with maize to utilize the land efficiently, increase ground cover while providing the N through biological fixation, and add organic manure to soil. Intercropping of cereals and legumes not only sustain productivity but also offers the opportunity to increase the use of symbiotically fixed N (Das et al. 2014a). Organic production of rice, pea, lentil, French bean, soybean, groundnut, etc. has been reported to sustain soil health and crop productivity in NER India (Das et al. 2014a). Some important futuristic cropping systems of Northeast India are given in Table 2.10.

2.6.2 Legume Cropping in Western and Central Himalayas

The farmers of western and central Himalayas have been practicing low-input agriculture with major emphasis on conserving crop biodiversity both at species and intraspecies level (Bisht et al. 2006; Meena et al. 2015c). The region has two distinct crop seasons upon which cropping patterns are evolved, viz., the winter or rabi season (from October to March) and the summer or *kharif* season (from April to October). The agriculture is predominantly rainfed (85%), and area under irrigation is only about 15% (Maikhuri et al. 1996). Rice and wheat are the most important crops in irrigated farms, whereas indigenous crops like *Amaranthus viridis*, *Eleusine coracana*, *Panicum miliaceum*, *Hordeum vulgare*, and *Setaria italica* and various legume crops like *Vigna radiata*, *Macrotyloma uniflorum*, *V. angularis*, *V. unguiculata*, *Pisum arvense*, *Glycine max*, etc. are raised in rainfed farms. The farm area under rainfed conditions is generally divided into two equal halves locally called as “Mullasari” and “Mallasari.” Grain legumes are basically rainy season crop raised under rainfed conditions. Some leguminous crops like pea and lentil are cultivated during post-rainy (*rabi*) season. Some of these pulses are cultivated on the field bunds of rice fields in irrigated land, whereas few are grown only in kitchen gardens. In greater Himalayan region, legumes are mostly mixed with traditional nonlegumes like millets (*Eleusine*, *Echinochloa*, sorghum, and maize) and pseudocereals

Table 2.10 Present and futuristic cropping systems with pulses in Northeast India

State	Existing cropping system	Futuristic cropping system with pulses
Sikkim	Maize-fallow	Maize-*pahenlo* dal-buckwheat
	Maize-rice	Maize-vegetables pea
	Maize-rapeseed	Maize-*pahenlo* dal-rapeseed
	Maize-buckwheat	Maize + bean-rapeseed
Manipur	Rice-fallow	Rice-pea/lentil
	Vegetable-fallow	Rice-broad bean
	Rice-rice	Maize-broad bean
Meghalaya	Rice-fallow	Rice-pea/lentil/rapeseed
	Maize-fallow	Maize-French bean/black gram/rapeseed
	Rice-vegetables	French bean/carrot/potato-okra-French bean/ rajmash
	Ginger/turmeric-fallow	Maize + soybean/groundnut-potato/tomato/French bean
		Broccoli-potato-rajmash/French bean
		Ginger/turmeric + soybean-rice bean
Tripura	Rice-rice	Rice-pea/lentil/rapeseed
	Rice-fallow	Rice-rice-pea/lentil
	Vegetable-fallow	Maize-rice-pea/lentil
		Maize-black gram/green gram
Nagaland	Rice-fallow	Rice-pea/lentil (lowlands)
	Maize-fallow	Maize-pulses (French bean, black gram)
Arunachal Pradesh	Rice-fallow	Rice-pea/lentil (lowland)
	Maize-fallow	Maize + soybean-French bean/black gram
Mizoram	Rice-fallow	Rice-pea/lentil (lowland)
	Maize-fallow	Maize + soybean-French bean/black gram/green gram

Source: Pattanayak and Das (2017); Das et al. (2016)

(*Amaranthus*, *buckwheat*, etc.). As many as 10–12 crops are grown together by the hill farmers with the objective to obtain maximum and diverse yield on per unit area basis (Shiva and Vanaja 1993; Ghosh and Dhyani 2004). Inclusion of nonleguminous crops like sorghum, maize, millets, etc. with legumes like French bean, cowpea, etc. provides support for climbing to the legume component and minimizes risks of disease and weed problems and also the harmful impacts of intensive cultivation of cereals on soil fertility. Cultivation of legume crops is much simple and requires less labor and attention than other crops. Rainy season legumes hardly require any irrigation, and rainwater is sufficient to meet its water requirement of the crop. At vegetative stage, when the crop roots grasp the soil firmly, a local farm implement called "Maaua" is operated in the field for soil loosening. Green and succulent pods of some legumes like *French bean* and cowpea are harvested early for use as green vegetables, but grains get ready for harvest around 125–135 days (Dhanai et al. 2016).

2.7 Cereal + Legume Intercropping

In intercropping, the crops are arranged in definite rows. Sowing of both main and intercrops may be done simultaneously or in staggered manner. Similarly, harvesting time may also differ. Intercropping ensures desired plant stand due to definite row arrangement and, hence, facilitates easy cultural operation, spraying of pesticides and harvesting, and higher returns. The major principles of intercropping are the varied and contrasting maturities, height and rooting pattern, nutrition needs, etc. so that the component crops in intercropping complement each other rather than competing for the resources such as water, light, nutrient, space, etc. and reduce risks of climatic adversities. Intercropping is particularly more productive under rainfed conditions due to climatic anomalies and poor availability of farming resources like credit, inputs, etc. Pulses are intercropped with cereals, oilseeds, millets, vegetables, etc. for efficient use of natural resources and assured income by small and marginal farmers (Ghosh et al. 2016, Das et al., 2016; Meena et al. 2017c).

Intercropping is a common practice, not only in the central Himalayas, India, but worldwide because it minimizes the risk of crop failure due to adverse effects of pests, improves the use of limited resources, reduces soil erosion, increases yield stability, and is cost-effective (Chandra et al. 2013). Several scientists have been working with cereal-legume intercropping systems (Dwivedi et al. 2015) and proved its success compared to the monocrops. Common crop combinations in intercropping systems of this region are cereal + legume, particularly maize + cowpea, maize + soybean, maize + pigeon pea, maize + groundnuts, maize + beans, sorghum + cowpea, millet + groundnuts, and rice + pulses (Dwivedi et al. 2015). Intercropping of cereals and legumes would be valuable because the component crops can utilize different sources of N (Chu et al., 2004). The cereal may be more competitive than the legume for soil mineral N, but the legume can fix N symbiotically if effective strains of *Rhizobium* are present in the soil. Intercropping is much less risky than monocropping considering that if one crop of a mixture fails, the component crops may still be harvested. Biological nitrogen fixation is the major source of nitrogen in legume-cereal mixed cropping systems when nitrogen fertilizer is limited (Fujita et al., 1992). Moreover, because inorganic fertilizers have much environmental damage such as nitrate pollution, legumes grown in intercropping are regarded as a sustainable and alternative way of introducing N into lower-input agroecosystems (Fustec et al., 2010). In addition, roots of the legume component can decompose and release nitrogen into the soil where it made available to subsequent crops. Intercrops of maize with legumes (e.g., maize + cow pea) can also substantially increase forage quantity and quality and decrease the requirements for protein supplements compared with maize sole crops (Javanmard et al. 2009). The amount of nitrogen fixed by the legume component in cereal-legume intercropping systems depends on several factors, such as species, plant morphology, density of component crops, rooting ability, type of management, and competitive abilities of the component crops (Dwivedi et al. 2015).

Table 2.11 Land equivalent ratio (LER) as affected by intercropping

System	LER	Location	References
Maize + soybean (2:2)	1.41	Northwest Himalayas	Pandey et al. (1999)
Maize + green gram (1:1)	1.54	West Bengal	Patra et al. (1999)
Maize + grain legume	1.22–1.54	Uttarakhand	Khola et al. (1999)
Maize + field pea (1:1)	1.51	Uttarakhand	Devi (2014)
Maize + field pea (2:2)	1.60	Uttarakhand	Devi (2014)
Maize + cowpea (1:2)	1.63	Eastern Himalayas	Choudhary et al. (2014)
Maize + French bean (1:2)	1.75	Eastern Himalayas	Choudhary et al. (2014)
Maize + black gram (1:2)	1.66	Eastern Himalayas	Choudhary et al. (2014)

Intercropping with legumes has a positive impact on symbiosis for nitrogen fixation and increasing soil fertility. The infertile land requires more nitrogen for proper plant growth and better yield, and thus the demand for soil nitrogen in Himalayan rainfed agriculture is increasing day-by-day. Unique characteristics like high protein content (2–3 times more than cereals), nitrogen-fixing ability, soil ameliorative properties, and ability to thrive better under unfavorable conditions make pulses an integral component of agriculture and cuisine in central Himalayas (Chandra et al. 2013). When nonleguminous crops like maize and millets are with legumes, they provide support for climbing to the latter, minimize disease and weed problems, and alleviate the negative impacts of continuous cereal cultivation on soil fertility. Five years study on a sloping land (35% slope) in eastern Himalayas (1000 m ASL) revealed that the average maize equivalent yield (MEY) was the highest for rice-lentil system (16.2 Mg/ha) followed by maize-French bean (14.6 Mg/ha) and maize-rapeseed system (9.01 Mg/ha), while the lowest MEY was recorded in monocropped farmers' practice (3.08 Mg/ha). Soil organic carbon (SOC) stock in the fifth year of study at 0–30 cm was much higher under maize-French bean system (61.4 Mg/ha) compared to monocropped maize (55.4 Mg/ha) (Rajkhowa et al. 2016). Land equivalent ratio (LER) indicates the area which will be required to produce the same productivity as that of an intercropping system. Intercropping of pulses with cereals like maize is reported to give LER of 1.22 to as high as 1.75 in different locations of IHR (Table 2.11).

2.7.1 Effect of Legumes on Succeeding/Associated Crops

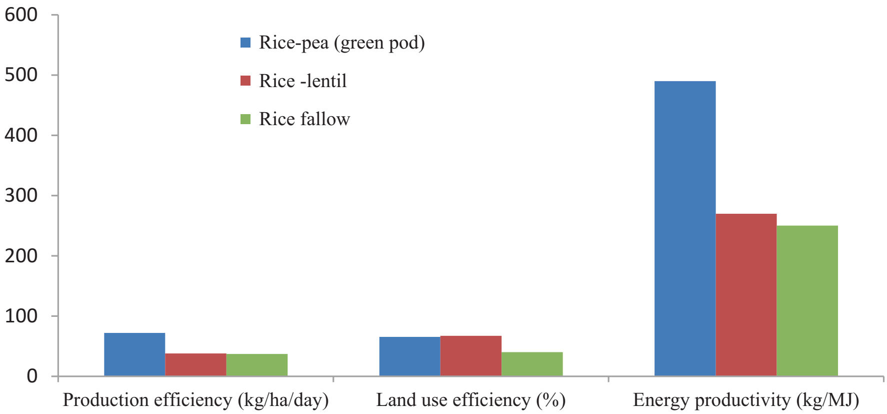
Legumes improve soil fertility and increase yield of the subsequent or associated crops; the extent of such benefits however largely depends upon the total plant biomass production, N_2 fixation, amount of N added to the soil through roots and nodules, and the leaf fall which are governed by agroclimatic and management practices to a great extent (Wani et al. 1994). Various research findings suggest that the carry-over of N for succeeding crops may be 60–120 kg in berseem (*Trifolium alexandrinum*), 75 kg in Indian clover (*Medicago sativa*), 75 kg in cluster bean

(*Cyamopsis tetragonoloba*), 35–60 kg in fodder cowpea (*Vigna sinensis*), 68 kg in chickpea (*Cicer arietinum*), 55 kg in black gram (*Vigna radiata*), 54–58 kg in groundnut (*Arachis hypogaea*), 50–51 kg in soybean (*Glycine max*), 50 kg in Lathyrus, and 36–42 kg per ha in pigeon pea (*Cajanus cajan*) (Das and Ghosh 2012). Legumes with indeterminate growth are more efficient in N fixation capacity than determinate types.

Fodder legumes in general are more potent in increasing the productivity of succeeding cereals. Through a symbiotic association with legumes, *Rhizobium* bacteria can convert atmospheric N into an organic form in the root nodules of crops. The accumulation of N depends on the length of the growing season, local climate and soil conditions. If a legume is grown as a green manure crop, biomass N produced can (in some cases) supply the entire N requirement for the subsequent crop. The proportion of N from N fixation in crops ranges from zero – usually where environmental stresses are severe and prevent nodulation – to 98% in crops grown under ideal conditions. The amount of N fixed has been recorded as up to 450 kg/ha/crop in the tropics. Legume residues contain P, potassium, and other nutrients that are recycled in relatively available forms for subsequent crops (Meena et al. 2014).

2.8 Role of Legume in Improving Input Use Efficiency

Legumes are more efficient in using scarce natural resources like water, nutrients, etc. than cereals. Inclusion of legumes in cereal-based cropping systems enhances equivalent yield, production efficiency, land use efficiency (LUE), energy productivity (Fig. 2.6), water use efficiency (WUE), water productivity, benefit/cost (B:C) ratio, employment generation, etc. (Das et al. 2014b, c; Ngangom et al. 2017c).



Source: Das et al. (2014b)

Fig. 2.6 Production efficiency, land use efficiency, and energy productivity as affected by inclusion of pulses in rice-fallow. (Source: Das et al. 2014b, c)

Table 2.12 Equivalent yield, WUE, water productivity, B:C ratio, and employment generation as affected by inclusion of pulses in rice and maize-fallow

Crop sequence	Rice/ maizeequivalent yield (Mg/ha)	WUE (kg/ ha.mm)	Waterproductivity (kg/m^3 water)	B:Cratio	Employment (man-days/ ha. year)
Rice-based cropping systems					
Rice-pea	10.72	19.69	0.64	5.78	230
Rice-lentil	6.42	12.34	0.34	2.24	210
Rice-fallow	3.26	5.99	0.18	2.17	100
Maize-based cropping systems					
Maize-French bean	7.07	11.58	0.32	3.88	150
Maize-rapeseed	3.84	6.98	0.23	2.30	110
Maize-fallow	2.64	6.23	0.16	2.39	60

Source: Das et al. (2014b)

The rice equivalent yield (REY) obtained with rice-pea sequence under CA was 229% higher compared to farmers' practice (FP) of rice monocropping at mid-altitude of Meghalaya in EHR. Similarly, maize-French bean under CA recorded 168% higher maize equivalent yield (MEY) compared to that of maize monocropping in Meghalaya hills (Das et al. 2014a). The enhancement in net return with maize-French bean and rice-pea under CA over respective FP were as high as 465 and 360%, respectively. Similarly, water use efficiency (WUE) enhanced by 228% under rice-pea sequence relative to monocropping of rice in mid-altitude of Meghalaya (Table 2.12). In the same study, the water productivity achieved with rice-pea (INR 9.57 m^{-3} water) and maize-French bean (INR 6.59 m^{-3} water) sequences under CA was significantly higher compared to that under FP of monocropping rice (INR 2.66 m^{-3} water) and maize (INR 1.80 m^{-3} water). Thus, the study indicated opportunity of CA cereal-pulse system in EHR for conserving natural resources and enhancing productivity (Das et al., 2014a). Production efficiency, land use efficiency, and energy use efficiency have been reported to increase when pea or lentil included as winter crop after lowland rice in HER (Das et al. 2014c).

Replacing traditional maize-wheat system with baby corn + French bean-pea-summer squash increased maize grain equivalent yield (190.8%), production efficiency (190.5%), productivity of the system (182.1%), gross returns (121.0%), net returns (176.4%), B:C ratio (64.1%), and profitability of the system (176.4%) in Palampur, Himachal Pradesh (Ramesh et al. 2016). They also reported that integrated nutrient management (75% RDF + 25% through FYM) also significantly increased maize grain equivalent yield by 4.3% over recommended dose of fertilizers. Padhi et al. (2010) found significant increase in grain yield of finger millet taken after cowpea (20 and 37%) and cluster bean (11 and 37%) grown for fodder or incorporation after harvest of green pods during *kharif* season compared to single crop of finger millet, respectively. In a study conducted at Pantnagar, Uttarakhand, Devi and Singh (2015) reported that intercropping of baby corn with field pea, besides increasing total production per unit area, also suppresses weed growth (33.78% and 30.68% higher weed control efficiency than sole baby corn and sole pea, respectively) and

Table 2.13 Effect of cropping sequence on equivalent yield, energy use efficiency, and income

Cropping system	System productivity (kg/ha per day)	Net energy return (x 000, MJ/ha)	Energy use efficiency (output/input ratio)	Energy productivity (g/ MJ)	Water use efficiency (kg/ha per mm)
Maize	4.0	11.49	10.10	0.317	4.74
Soybean	3.53	6.07	6.96	0.427	4.77
Groundnut	4.23	4.76	5.51	0.606	7.19
1:2 maize/ soybean	5.35	14.70	9.47	0.308	6.22
1:5 maize/ soybean	5.61	13.55	10.80	0.406	6.47
1:2 maize/ groundnut	5.75	14.24	9.07	0.326	6.77
1:5 maize/ groundnut	6.22	12.64	9.92	0.439	7.26

Source: Modified from Choudhury and Kumar (2016)

severity of diseases. Appropriate legume intercrop and planting geometry (row ratio) allow better light interception to the crop canopy and improve performance of cereal-based cropping system. In a study on eastern Himalayan region (Table 2.13), soybean and groundnut intercropping in different row ratios with maize resulted in improvement of water use efficiency by 83.2%, harvest monetary benefit by 87.5%, benefit/cost ratio by 92.3%, and energy productivity by 38.5% with 1:5 row ratios of maize/groundnut over solitary maize (Meena et al. 2015a; Choudhury and Kumar 2016). Choudhary et al. (2014) reported that the amount of N, P, and K removed by weeds was less in intercropping system of maize with pulses (cowpea, French bean, black gram) as compared with sole maize plot. Water use efficiency improved by 83.2%, harvest monetary benefit by 87.5%, benefit/cost ratio by 92.3%, and energy productivity by 38.5% with maize-groundnut intercropping (1:5) over solitary maize (Choudhary and Kumar 2016). They also reported that increased in interception of solar radiation in the bottom of the canopy ranged from 19% to 33% in an intercropping system of maize with groundnut and soybean.

2.8.1 Weed Smothering Efficiency of Pulses

Crops like rice and maize which are grown during rainy season suffer from excessive weed problem due to favorable climatic and microenvironmental conditions, causing a huge loss to productivity and income of farmers (Choudhury et al. 2015b; Dadhich et al. 2015). Maize being a wide-spaced crop and mostly cultivated during rainy season suffers from severe weed competition leading to 30–70% yield loss (Hugar and Palled, 2008). Intercropping of legumes provides the opportunities to suppress the weeds in addition to increasing system productivity (Banik et al. 2006). In a study on maize + legume intercropping system in Basar (660 m ASL), Arunachal Pradesh by Choudhary et al. (2014) reported that weed density were higher under sole maize followed by intercropping of 1:1 row proportion of maize with groundnut or maize with soybean. Soybean sole crop (66.7%) followed by 1:5 maize/soybean intercropping (56.4%) registered higher weed smothering efficiency over sole maize. Thus, intercropping of maize with groundnut or soybean in eastern Himalayan region enhanced system productivity and suppressed weeds. The maize-growing areas in the country are mostly under maize-legume systems. However, from region to region the differences lie mainly in the varieties and legume species. Grain legumes are mostly grown as intercrops, in sequence or rotations with maize in mid-altitude subhumid (common beans and soybean), highlands (faba bean and chickpea), dry land (common bean, pigeon pea, cowpea, and groundnut), and low-altitude subhumid (cowpea) agroclimatic conditions (Dwivedi et al., 2016). Intercropping of finger millet with black gram at a density not exceeding 75% of a sole black gram culture may improve overall yields and income from mountain agriculture system (Chandra et al., 2013). Intercropping of soybean with rice (4:2) has been reported to enhance system productivity and soil fertility in mid-altitude subtropical EHR (Das et al. 2014d).

2.9 Opportunity for Pulses Under Conservation Agriculture (CA) in NER

Excessive tillage may result in short-term increase in fertility but degrades soils in the medium and long run through structural degradation, loss of organic matter, erosion, and falling biodiversity. In order to keep production system in different land situations sustainable, CA based on minimum/no-till (NT) system, optimum residue management, and crop rotation is an alternative to conciliate agriculture with its environment and overcome the imposed constraints of the climate change and continuous escalation of inputs costs. Pulses do not need fine seed bed; they perform well even on rough seed bed with good aeration. Thus, there is good scope for adoption of conservation tillage in pulses (Kumar et al. 2016). Land configuration like raised and sunken beds or modified furrow-irrigated raised beds is also having good scope in poorly drained soils as pulses can be cultivated on the raised beds and water-loving crops like rice can be cultivated in the sunken beds (Das et al. 2014a). Conventionally in NER, after *kharif* rice, fields remain fallow in lowland, mainly due to excess moisture owing to seepage from surrounding hillocks in mid altitudes. A simple drainage around the rice fields/plots with appropriate outlets at physiological maturity creates the desirable situations for cultivation of pulse crops like pea and lentil (Das et al. 2012). Das et al. (2011) reported that among various field pea varieties tried, Prakash, Vikash, IPFD 99–13 recorded maximum green pod yield followed by IPFD 1–10-(3.29 Mg/ha), IPFD −99-25, and HUDP. Among the lentil varieties tested, DPL-15, DPL 62, IPL81, and IPL406, l303 were found potential for NT cultivation in rice-fallows (Layek et al. 2014). It is also concluded that minimum tillage (MT) in rice followed by NT in pea/lentil was optimum for higher productivity of succeeding pea/lentil compared to conventional tillage (CT) in

Table 2.14 Yield attributes and yields of lentil as influenced by rice residue management practices under upland and lowland conditions

Ecosystems/residue management practices	Upland				Lowland			
	Pods/plant	Seeds/pod	1000 seed wt. (g)	Seed yield (Mg/ha)	Pods/plant	Seeds/pod	1000 seed wt. (g)	Seed yield (Mg/ha)
Residue retention	20.26	1.84	25.01	0.72	65.37	2.39	25.05	1.64
20 cm standing stubble	18.64	1.51	24.35	0.67	55.75	2.00	24.38	1.51
Residue removal	17.29	1.46	24.31	0.54	44.26	1.95	24.32	1.44
SEm±	0.53	0.05	0.08	0.03	1.01	0.05	0.09	0.06
CD (p = 0.05)	1.56	0.15	0.22	0.07	2.96	0.16	0.26	0.18

Source: Das et al. (2016)

rice-NT in pea/lentil and NT in rice-NT in pea/lentil under lowland conditions (Das et al. 2013). With appropriate agronomic interventions and varietal screening, pea and lentil could be popularized at mid-altitude for food and nutritional security of small and marginal farmers of the region (Ghosh et al. 2011). In a field study in Sikkim, Singh et al. (2015) reported significantly higher green pod yield (5.89 Mg/ha), gross returns (1.93×10^3 \$/ha; 1 \$ = 65 INR), net returns (1.48×10^3 \$ha), and B:C ratio (3.27) with NT over MT and CT. Similarly, NT required 44 and 28.3% less energy as compared to CT and MT, respectively. Inclusion of pulses, like pea and lentil, enhances farmers' income and employment substantially compared to rice-fallow or other systems. Farmer's net income enhanced by 446.2 \$/ha and 330.8 \$/ha over rice-fallow system due to inclusion of pea (vegetable) and lentil, respectively, in the system following NT practice (Das et al. 2012). Another field study in Meghalaya indicated that in situ retention of previous rice crop residues gave significantly higher grain yield of succeeding lentil (DPL 62) followed by 20 cm stubble under upland condition (Table 2.14). Similarly, yield enhancement of lentil due to in situ retention of previous rice crop residues was 14% higher compared to residue removal (1.44 Mg/ha) in lowland (NASF Annual Report 2015).

There is a good scope for expansion of small-seeded varieties of pulses like lentil, lathyrus, etc. under *utera* (*paira* cropping) cultivation in lowland rainfed rice-fallow land in NER (Das et al. 2014a). Field experiments conducted at ICAR Research Complex for NEH Region, Umiam, Meghalaya, on *utera* cultivation of lentil with rice recorded seed yield of 400 to 600 kg/ha (Das et al. 2014a). The *utera* cultivation can be more effective by using short-duration and high-yielding varieties of rice to vacate the field early giving sufficient time for pulse crop in the field.

Maize which is the second most important crop of NER is generally grown during *kharif* season in uplands, sloping lands, and shifting cultivated area. The early and timely sown maize (April/May) is harvested during July/August and allows cultivation of pulse crops like French bean, black gram, and green gram. Retention of standing stalk of previous maize crop (0.75– 1 m) followed by sowing of subsequent French bean crop by opening a narrow furrow in between two lines of previous maize crop using a NT seed drill or furrow opener is a recommended practice for conserving moisture, saving time, and enhancing CI in NER (Das et al. 2011). As maize is grown with a wider line spacing (60 cm), two lines of French bean/pulses (30 cm spacing) are accommodated in between two lines of previous maize. This method saves about 50% cost in staking besides conserving soil moisture, saving time, and improving soil quality. Similarly, black gram and green gram are grown under NT tillage with conserved moisture in maize-fallow producing a seed yield of 1–1.5 Mg/ha (Das et al. 2011).

2.10 Strategies for Enhancing Area and Productivity of Legumes

Pulse production and productivity in India have been stagnant for the last few decades even after several efforts and program. Due to their low productivity, pulses are grown as residual/alternate crops with minimal inputs mostly on marginal lands in IHR after taking care of food/income needs from high-input high-productivity crops like rice, maize, and other cereals by the most farmers (Das et al., 2016). Pulses are mostly grown as rainfed crops with negligible fertilizer or other agro-inputs leading to thirsty and hungry conditions (Meena et al. 2016). Thus, poor yield of pulses is mainly related to poor management practices owing to their relatively low status (crop of secondary importance) in the cropping system (Ghosh et al., 2016). Further, pulse crops are adversely affected by a large number of biotic (insect-pest, diseases, weed) and abiotic (water, nutrient, low temperature, etc.) stresses, which are responsible for instability and poor yields to a great extent. Some of the strategies to enhance area and productivity of legumes in IHR are as follows.

2.10.1 Horizontal Inclusion of Pulses in Cropping System

Cropping system is broadly grouped into sequential cropping and intercropping. Sequential cropping may be a regular rotation of different crops in which the crops follow a definite order of appearance on the land or it may consist of only one crop grown year after year on the same area. To enhance the pulse production, it must be included in cropping system either in sequential (horizontal) or intercropping (vertical) (Fig. 2.7). The prominent sequential cropping systems involving different pulses are indicated below.

Rice-lentil/field pea/lathyrus In recent years, development of early- to medium-maturing varieties of lentil suitable for planting up to mid of December (HUL-57) with yield potential of 1.0–1.2 Mg/ha has enabled farmers to adopt rice-lentil system instead of rice monocropping especially in the valley areas, where residual moisture is available (Ansari et al. 2015a). Rice/maize-lentil cropping system has been successfully demonstrated in Manipur Hills of EHR (Ansari et al. 2015b). Introduction of short-duration pea varieties is also another option to enhance pulse production. In Manipur, vegetable/garden pea after rainy season rice has been found

Fig. 2.7 Diversion of monocropping rice to rice-lentil sequential cropping system at Sekmai Hijam Khunou village, Thoubal district, Manipur

to be promising in terms of productivity and income. Lathyrus has also very good potential after rice as relay crop. *Makhyatmubi* is a local cultivar of pea which is very popular in Manipur, and it has very high potential in the valleys under rice-pea system (Ansari et al. 2015a).

Pigeon Pea-Mustard With the advent of short-duration cultivars of pigeon pea (UPAS-120, Manak and Pusa 992), it can be grown in *jhum* cultivated areas of EHR, where pigeon pea can mature in 130–150 days and rapeseed-mustard can be taken as sequence crop. This will provide desired stability and sustainability to productivity of fragile *jhum* land system by sustaining soil fertility due to leaf fall and N fixation by pigeon pea (Ansari et al., 2015b). But there are some issues, which need to be addressed for wider adoptability and profitability from this system. Presently, most of the short-duration varieties of pigeon pea available for cultivation are affected by sterility mosaic, fusarium wilt, and *Phytophthora* blight diseases and have tendency to prolong maturity with the late monsoon. Therefore, development and adoption of suitable varieties, which could mature by early November with high-yielding potential, are required (Das et al. 2016).

Rice/Maize-Urd Bean/Mung Bean Cultivation of *rabi*/summer urd bean and mung bean is getting momentum due to availability of short-duration suitable high-yield potential cultivars. Summer urd bean after rice and urd bean/mung bean/rajma after maize are having high potential in terrace and hill agriculture areas (Das et al. 2016). Babu et al. (2016) reported that maize (green cobs)-urd bean (*Pahenlo dal*)-buckwheat system was the most resource-efficient system and recorded significantly higher system productivity (8.89 Mg/ha), net return (4.67×10^3 \$/ha), B:C ratio (2.59), and employment generation (285 man-days/ha) over other cropping systems. With regard to the energetics, this system recorded 188.9, 192, 25.8, and 6.5% higher gross energy return, net energy return, energy use efficiency, and energy productivity, respectively, over maize-fallow rotation.

Rice-Broad Bean Broad bean is very popular and choicest food legume in Manipur due to its high market demand and price. It is cultivated across the Manipur after harvesting of cereals. The local broad bean is a long-duration crop. Due to introduction of high-yielding short-duration cultivars, maize-broad bean system is becoming in Manipur hills of EHR (Ansari et al. 2015a).

Rice Bean/Soybean-Mustard Rice bean is an indigenous legume crop of EHR and extensively grown in terraces, hill slope, and foot hills (except low land areas). Local cultivars have high-yield potential, but they are long duration in nature. Inclusion of high-yielding short-medium-duration cultivars of rice bean will provide enough opportunity to take mustard in sequential cropping (Das et al. 2016).

2.10.2 Vertical Inclusion of Pulses in Cropping System

Intercropping of pulses with cereals is more successful in terrace and *jhum* cultivated areas, where there is least possibility of water stagnation. Intercropping of pulses with maize is more popular in terrace cultivation, and mixed cropping of pulses with rice/maize is more popular in *jhum* cultivated areas of Manipur. Maize + rice bean (Fig. 2.8), maize + soybean, and maize + Urd bean/mung bean (Fig. 2.9) are more remunerative in *kharif* season. Perennial pigeon pea in intercropping system is generally grown on bunds with cereals, oilseeds, and pulses. In *rabi* season, mustard + lentil/lathyrus/pea, *Makhyatmubi* (local pea variety) + vegetables (Fig. 2.10), and broad bean + vegetables are more remunerative intercropping systems.

Fig. 2.8 Maize + rice bean grown in 2: 4 ratios in terrace land at ICAR Langol experimental farm, Manipur, maize harvested during pod initiation stage, and maize stalk act as support for trailing

Fig. 2.9 Maize + soybean (left) and maize + urd bean (right) intercropping systems

Fig. 2.10 *Makhyatmubi* (local pea variety) + cabbage and maize + pigeon pea intercropping at Thoubal, Manipur

2.10.3 Cultivation of Pulses in Field Bund

In IHR, due to difficult terrain, steep slope, erosion hazard, etc., in most of the cases, up to 10% of the cultivated land is left for field bunds, terrace risers, and other conservation measures. In these bunds, pulses like pigeon pea, soybean, green gram, black gram, etc. can be grown. This practice besides increasing pulse production and income will help in conserving soil, water, and other natural resources (Das et al. 2016). Similar practice is also popular in other Himalayan countries like Nepal (Gharti et al. 2014).

2.10.4 Inclusion of Pulses in Shifting Cultivation

The continuance of *jhum* in the NER is closely linked to ecological, socioeconomic, cultural, and land tenure systems of tribal communities. Since the community owns the lands, the village council or elders divide the *jhum* land among families for their subsistence on a rotational basis in most *jhum* dominated areas. The dry broadcast method involves sowing in the month of March/April and harvesting in August/September. Wet sowing is done in the month of May/June and harvested during October/November. Shifting cultivation is widely practiced in hilly and sloping areas, and settled terrace farming is done in foothill or low slope areas, mostly near the adjacent rivers, streams, or other water sources. Depending on the slope, wet broadcast on bunded fields or dry broadcast on unbunded fields is practiced. In Nagaland, alder (*Alnus nepalensis*)-based *jhum* farming is common, where alder trees are maintained in the field by regular lopping and crops are cultivated in interspaces. Rice bean, soybean, pigeon pea, etc. are cultivated in *jhum* fields as mixed crop with rice, maize, and millets in the IHR (Das et al. 2016). There is tremendous opportunity to enhance pulses production especially in *Jhum* areas, where farmers are growing crops in mixed cropping on rotational basis. Some potential pulses for *jhum* areas are pigeon pea, rice bean, soybean, mung bean/urd bean, broad bean, Makhyatmubi, winged bean, cowpea, lima bean, and tree bean (*Parkia roxburghii* indigenous to Himalayan states like Manipur, Nagaland, etc.) either as sole cropping or intercropping or agroforestry system. One of the ways to increase yield in this area is adoption of intercropping system which is cultivation of two or more crop species in the same field with definite row proportions. In intercropping system, crops are complementary in terms of growth pattern, aboveground canopy, rooting system, and their water and nutrient demand (Singh et al. 2008).

2.10.5 Farm Mechanization

Large proportions of cultivated area in IHR are hilly and mountainous, and farm mechanization is nonexistent. As compared to other parts of the country, low-cost farm machineries and implements for the hilly terrains should be made available for the farmers.

2.10.6 Transfer of Technology

Transfer of technology programs (farmers' trainings, frontline demonstrations, sensitization programs, etc.) have to be organized to familiarize the farmers with the improved production technology of pulse crops and hammer home the point that yield will increase substantially if these crops are grown as per the recommended package of practices. Such programs are very important to bridge the gap between actual and potential yield of legume crops.

2.11 Future Perspectives

The population of India will grow to about 1.69 billion by 2050, and the total pulse requirement will be 32 million tons. Similarly the IHR population will also grow due to poor and marginal nature of the farmers, low level of education, and dependence on agriculture as source of livelihood. To meet the required level of pulse production, an annual growth rate of 2.2% is required (Singh and Pratap, 2015). EHR alone has about 1.5 million hectare area under rice-fallow and a substantial area under maize fallows. Bringing these areas under pulses (at least 25% area) will contribute significantly to improving pulses scenario of the IHR and country (Das et al. 2014a,c). Reducing postharvest losses to the tune of 10–15% from the current losses will also add to ~ 1 million tons of pulses. Since pulses are the most important constituents of vegetarian diets for supplementing proteins, target-oriented breeding strategies are required for improving the content and quality of proteins in these. The availability of critical inputs like quality seeds, manure, biofertilizers, micronutrient, biopesticides, etc. and lifesaving irrigation through micro-irrigation and rainwater harvesting and its efficient utilization will further lead toward reducing the yield gaps in pulses. Efforts are to be focused on development of bio-intensive eco-friendly integrated pest management module for managing the major insect pests and diseases which restricts adequate benefit from pulses. To combat abiotic stresses such as drought, water logging, etc., wild gene pool is being explored to introgress resistance/tolerance genes through pre-breeding activities (Singh and Pratap, 2015). IHR being vulnerable to various kinds of land degradation due high rainfall, mono-cropping, faulty cultivation practices, steep slopes, and low use of manure and fertilizers, legumes, and pulses will have to play a vital role for providing food security and soil sustainability in the region (Das et al. 2016). There is an urgent need to initiate a National Mission on Pulses specific to IHR for food, nutritional, and environmental security of the fragile ecosystem of the world. It is rightly said that "a good health of Himalayas will ensure a good health of the country and possibly the world." Thus, all stakeholders has to join hand to save the Himalayan Ecosystem and agriculture through dissemination and demonstration of sustainable best practices like inclusion of legumes and pulses in cropping systems among many other approaches.

2.12 Conclusion

India is the largest pulse producer and consumer of the world, but ironically our pulse demand is not fulfilled by the home-grown pulses rather depend on the import which create heavy burden on the government exchequer and also raise the question on the various stakeholder involved in agriculture. The answer lies within the system only, but it requires the concerted effort of all, right from the farmers to policy makers. The potential of the IHR in legume production is still untapped as the entire region provides the opportunity in the rice/maize-fallow area for pulse production. The entire region consider pulses as the crop of secondary importance due to which it does not attract much of the farmer's crop management attention. There is the need of mass awareness campaign in the entire region on the multifarious benefits of legumes such as enriching the soil with the available nitrogen, conserves soil and nutrients by reducing runoff and erosion, a source of plant proteins, mitigating greenhouse gases emissions, breaking the cycles of pests and diseases through crop diversification, and contributing to balance the deficit in plant protein production. In the present climate variability and degrading natural resource scenario, pulses should be given the enough attention at the field level in the entire Indian Himalayan Region for livelihood security and environmental sustainability.

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