CHAPTER-2

Theoretical Orientation: What are Pulses ?

Pulses are part of the legume family, but the term "pulse" refers only to the dried seed. Dried peas, edible beans, lentils and chickpeas are the most common varieties of pulses. Pulses are very high in protein and fibre, and are low in fat. Like their cousins in the legume family, pulses are nitrogen-fixing crops that improve the environmental sustainability of annual cropping systems. Pulses come in a variety of shapes, sizes and colours and can be consumed in many forms including whole or split, ground in to flours or separated into fractions such as protein, fibre and starch.

Pulses are a source of supplementary protein to daily diets based on cereals and starchy food for a predominantly vegetarian population and for those who cannot afford expensive animal protein. Pulses are a great tasting addition to any diet. They are rich in fibre and protein, and have high levels of minerals such as iron, zinc, and phosphorous as well as folate and other

B-vitamins. In addition to their nutritional profile and links to improved health, pulses are unique foods in their ability to reduce the environmental footprint of our grocery carts. Put it all together and these sensational seeds are a powerful food ingredient that can be used to deliver the results of healthy people and a healthy planet. They also provide energy, essential minerals, vitamins and several compounds considered beneficial for good health. Their cultivation enriches soil by adding nitrogen, and improves the physical, chemical and biological soil properties.

Pulses are grown since ages in different parts of the world. They are well suited to diverse environments and fit in various cropping systems owing to their wide adaptability, low input requirements, fast growth, nitrogen fixing and weed smothering ability. Their short growing period and photoperiod sensitivity make them suitable for crop intensification and diversification.

The demand of pulses is fast increasing, both in developed and developing countries, where they meet the minimum protein requirements of an increasing population turning to a vegetarian diet. Their productivity can be doubled by improved cultivars and by modern production technologies.

Pulses in Historical agriculture:

Since most primitive mode of human life agricultural systems were evolved to fulfill the changing needs of human being. When the primitive man faced the problems in gathering his food in the form of edible fruits, seeds, roots leaves etc. and failed to have year-round supply, he entered the phase of hunting. Later he turned to animal husbandry i.e. protecting the herds from natural predators, guided to good grazing and care of water and so on.

Further human interest grew in animal breeding, feeding and cropping of the herd or flock and protection from predators as well as diseases to the best of his ability. This made them to migrate periodically to sustain the feeding requirements of the herds and became nomadic which later settled around perennial water supplies.

Modern agriculture thus is originated for convenience in food gathering habit of human being which has been originated by propagating the useful plants near his own homestead from the seeds and vegetative propagation materials, collected from the experiences of pre-agricultural community. An organized form of this practice is nothing but Agriculture.

Human dietary considerations in the course of these developments had major impact on the selection during the domestication of pulses. Although the analytical profile of amino-acids of cereals and pulses was not available, the well-nourished community with balanced diet must have experienced the health benefits which led to use of complementary mixtures of cereals and pulses. There can be additional considerations of benefits to the domesticated animal herds from the use of pulses in feed and benefits in terms of soil health for perpetuating pulses in the agricultural systems, more particularly in arid and semi-arid tropical regions.

The word legume comes from *legere* meaning “to gather” which indicates that the seed were collected by hand instead of being threshed from the plants like cereals. Thus, legume has necessarily the characteristics of collecting seeds before it is shattered due to dehiscence of pods, which is very common in wild forms.

Domestication of pulses:

Eevolution of pulses and concluded that selection against explosive dehiscence of pods which results in shattering of grains was the most important trait against which the selection was operated during the course of domestication of legumes for food. The species thus brought under cultivation has at least delayed dehiscence of the pod if not suppressed totally.

It has been well accepted that in evolutionary history of plants the inbreeders have been originated from out-breeders. The change from an allogamus to autogamous breeding system may sometime depends on simple genetically governed mechanisms like cleistogamy in Pigeonpea (Mahta and Dave, 1931; Datta and Deb, 1970; Saxena *et al.* 1987).With the exceptions of *Vicia faba* and *Phaseolus coccineus*, most of the pulses had already abandoned exogamy before domestication, although the floral structure is well adapted to cross pollination.

Similar to most of the domesticated agricultural plant species the morphological changes in terms of improved size of fruits and seeds are equally concerned to pulses. The increased leaf size without much rise in plant dry matter means plant less freely branched with fewer larger leaves which is likely to be occurred during evolution of such species through the change from many thin wiry stems/branches bearing numerous small leaves. Cowpea, chickpea and soybean are cited as another few examples in which a restriction of branching during evolution is accompanied by compensating increase in those parts (leaves, pods, seeds) and reduction in their number, finally resulting in a very compact, more or less erect growth form suited to better adaptation in the agricultural system.

Physiological changes associated with the developments have also gone through similar selection, may not be deliberate one. Moreover all these changes in domestication are related to ability of plant to yield the economic products, many times it may be seeds of desirable quality. Selection toward annual growth habit must have an important role in adoption of most of legumes, wild forms of which are seen to be perennial.

Under domestication of pulses there is every possibility to have selection pressure to adopt them to the changing environment. Kabuli chickpea recently placed in southern peninsular India is a unique example of selection of early flowering, fast growing in early seedling stage to suit to a short-mild winter environment.

The nutritional value of pulses:

Pulses are basically dried edible seeds obtained from plants. A good source of proteins, they are a staple food in many parts of the world. In the tropical areas especially, pulses are one of the most important food groups after cereals. In fact, pulses are a good source of nutrition as they have significant quantities of both proteins and calories.

Pulses are low fat source of protein, with a high fibre content and low glycaemic index:

- Pulses are very high in fibre, containing both soluble and insoluble fibres. Soluble fibre helps to decrease blood cholesterol levels and control blood sugar levels, and insoluble fibre helps with digestion and regularity.

- Pulses provide important amounts of vitamins and mineral. Some of the key minerals in pulses include iron, potassium, magnesium and zinc. Pulses are also particularly abundant in B vitamins including folate, thiamine and niacin.
- Pulses typically contain about twice the amount of protein found in whole grain cereals like wheat, oats, barley and rice
- Finally, pulses are an important source of proteins and in most developing countries constitute the main source of protein for most populations.

In addition to contributing to a healthy, balanced diet, pulses nutritional qualities makes them particularly helpful in the fight against some non-communicable diseases.

The World Health Organisation estimates that up to 80% of heart disease, stroke, and type 2 diabetes and over a third of cancers could be prevented by eliminating risk factors, such as unhealthy diets and promoting better eating habits, of which pulses are an essential component.

Up to 80% of heart disease, stroke, and type 2 diabetes and over a third of cancers could be prevented by eliminating shared risk factors, mainly tobacco use, unhealthy diet, physical inactivity and the harmful use of alcohol

Pulses can help lower blood cholesterol and attenuate blood glucose, which are a key factors in the fight against diabetes and cardiovascular disease.

Eating pulses as a replacement to some animal protein also helps limit the intake of saturated fats and increases the intake of fibres.

Pulses have also been shown to be helpful in the prevention of certain cancers, because of their fibre content but also because of their mineral and amino-acid contents, in particular folate.

Pulses are included in all 'food baskets' and dietary guidelines. The World Food Programme (WFP) for instance includes 60 grams of pulses in its typical food basket, alongside cereals, oils and sugar and salt.

Encouraging awareness of the nutritional value of pulses can help consumers adopt healthier diets. In developing countries, where the trend in dietary choices tends to go towards more animal based protein and cereals, retaining pulses is an important way to ensure diets remain balanced and to avoid the increase in non-communicable disease often associated with diet transitions and rising incomes.

Several studies have shown that legumes are been associated with long-lived food cultures such as the Japanese (soy, tofu, natto, miso), the Swedes (brown beans, peas), and the Mediterranean people (lentils, chickpeas, white beans) and that they could be an important dietary factor in improving longevity.

Table 1: Nutriotion values of different pulses

Nutritive Values of different pulses commonly used in India

Sl. No.	Pulses (100g)	Protein (g)	Fat (g)	Carbohdrate (g)	Energy (kCal)	Crude fibre (g)	Calcium (mg)	Iron (mg)
1	Bengal gram	17.1	5.3	60.9	360	3.9	202	4.6
2	Black gram	24	1.4	59.6	347	0.9	154	3.8
3	Cow pea	24.1	1.0	54.5	323	3.8	77	8.6
4	Field bean	24.9	0.8	60.1	347	1.4	60	2.7
5	Green gram (Whole)	24	1.3	56.7	334	4.1	124	4.4
6	Green gram (Split)	24.5	1.2	59.9	348	0.8	75	3.9
7	Horse gram	22	0.5	57.2	321	5.3	287	6.77
8	Kesari dhal	22	0.6	56.6	345	2.3	90	6.3
9	Peas (green)	7.2	0.1	15.9	93	4.0	20	1.5
10	Peas (dry)	19.7	1.1	56.5	315	4.5	75	7.05
11	Rajmah	22.9	1.3	60.6	346	4.8	260	5.1
12	Red gram	22.3	1.7	57.6	335	1.5	73	2.7
13	Soyabean	43.2	19.5	20.9	432	3.7	240	10.4
14	Ground nut	25.3	40.1	26.1	567	3.1	90	2.5

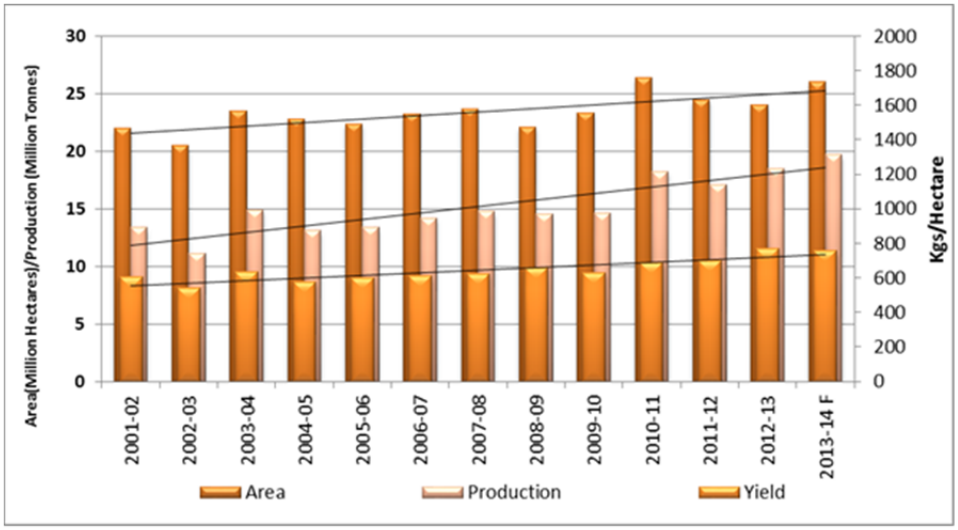
Production Trend:

In India pulses are cultivated on marginal lands under rain fed conditions. Only 15% of the area under pulses has assured irrigation. Because of the high level of fluctuations in pulse production (due to biotic and abiotic stress) and prices (in the absence of an effective government price support mechanism) farmers are not very keen on taking up pulse cultivation despite high wholesale pulse prices in recent years. Farmers are getting attracted towards cash crops like Bt cotton, maize and oilseeds (mainly soybeans) because of better return and lower risk. Consequently area under these crops has increased over the years to the detriment of pulses (Table 2).

Table 2: Area Production and Yield of Total Pulses in India

Year	Area(million hectares)	Production(million tonnes)	Yield(kg./hectares)
1980-81	22.46	10.63	473
1990-91	24.66	14.26	578
2000-2001	20.35	11.08	544
2010-11	26.40	18.24	691
2011-12	24.46	17.09	699
2012-13	23.47	18.34	781

Nevertheless, improvement in yields, albeit modest, has contributed to higher pulse production in recent years (Fig. 1). Most of the increase in pulse production in recent years has been in gram (Fig. 2). Low pulse yield in India compared to other counties is attributed to poor spread of improved varieties and technologies, abrupt climatic changes, vulnerability to pests and diseases, and generally declining growth rate of total factor productivity



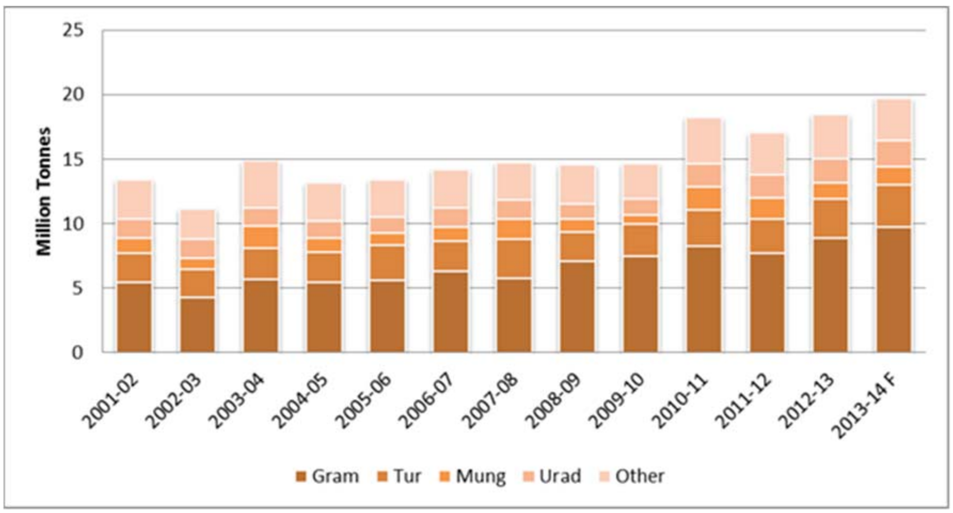
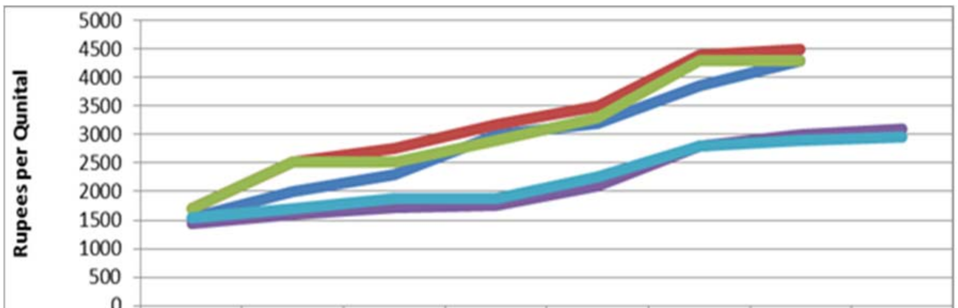


Fig. 1 & 2: Trend in Area, Yield, and Production of Pulses

In order to give the much needed fillip to pulse production, the government has included pulses in the NFSM (along with wheat and rice) since the launch of NFSM in October 2007 and has been significantly increasing the MSP for most pulses. Over the past four years, the increase in MSP was a massive 87 percent for tur, 71 percent for urd, and 63 percent for mung. Among rabi pulses MSP for gram for MY 2014-15 was fixed at Rs. 3,100 per quintal and masur at Rs, 2,950 per quintal, although a modest increase over the MY 2013-14 level of Rs. 3,000 and Rs. 2,900 per quintal, nevertheless a massive increase of 76 percent and 58 percent, respectively, since 2010-11 (Fig. 3).



	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
Tur	1550	2000	2300	3000	3200	3850	4300	
Mung	1700	2520	2760	3170	3500	4400	4500	
Urad	1700	2520	2520	2900	3300	4300	4300	
Gram	1445	1600	1730	1760	2100	2800	3000	3100
Masur	1545	1700	1870	1870	2250	2800	2900	2950

Fig. 3: Trend in Minimum Support Prices for Pulses

Consumption and prices

Pulse production has recorded less than one percent annual growth during the past 40 years, which is less than half of the growth rate in Indian human population. Consequently per capita production and availability of pulses in the country has witnessed sharp decline. Per capita net pulse availability has declined from around 60 grams per day in the 1950s to 40 grams in the 1980s and further to around 35 grams per day in 2000s. However, in the past four years, there has been significant increase in consumption averaging around 50 grams due to somewhat higher production, thanks to the National Food Security Mission (NFSM) focus on pulses, and larger imports, mostly of dry peas from Canada and Australia (Fig. 4).

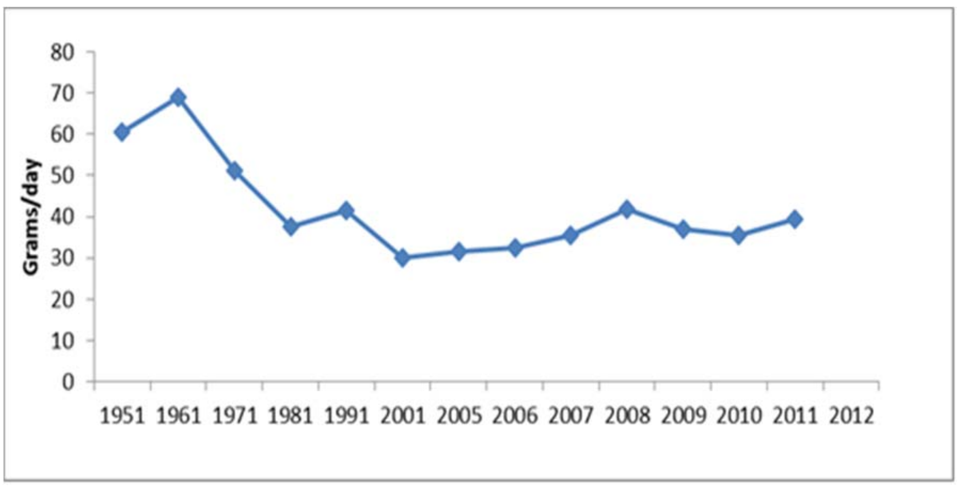
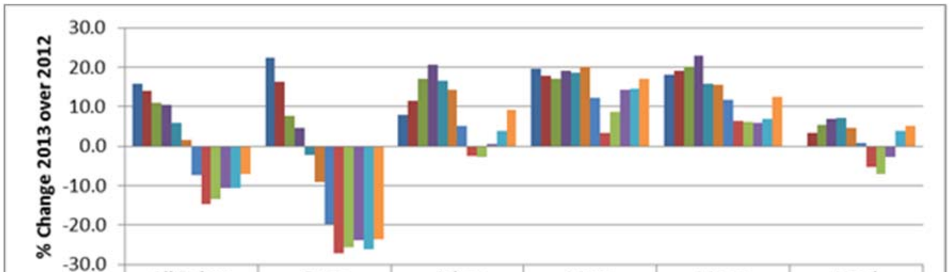


Fig. 4: Per capita net availability of pulses

Higher production combined with larger imports has resulted in a marginal increase in pulse consumption estimated at around 50 grams per day in 2012-13 compared to less than 40 grams prior to 2012-13. This level of consumption is estimated to have been maintained in 2013-14. Lager imports of dry peas in recent years due its lower international prices have resulted in its increased share in the domestic pulse consumption.

The increasing mismatch between production and consumption of pulses has resulted in larger imports of pulses in recent years. Imports of pulses in 2012-13 (Apr-Mar) were a record 4.0 million tonnes an increase of 500,000 tonnes over 2011-12. 2012-13 imports included 1.37 million tonnes of dry peas and dun peas (mattar), 506,000 tonnes of pigeon pea (tur), 642,000 tonnes of green pea (mung), 698,000 tonnes of chick peas, 506,000 tonnes of lentil (masur), 84,000 tonnes of kidney beans (rajma), 180,000 tonnes of other beans and 24,000 tonnes of other pulses. Imports in 2013-14 through November 2013 at 2 million tonnes were about 500,000 tonnes behind imports during the corresponding period of 2012-13 reflecting larger domestic production and higher cost of imported pulses due to the depreciation of Indian rupee against US$. Total imports in 2013-14 are projected at 3.5 million tonnes.

Domestic price inflation for pulses as a group measured by Wholesale Price Index remained in the negative territory since June 2013, largely due a significant decline in gram prices, the major pulse in India. Price inflation in other pulses, mainly mung and masur, although showing some declining trend, remained high in 2013 (see Fig. 5). Due to expected higher production of gram in 2014, price inflation of pulses as a group is likely to remain subdued in 2014-15, unless the 2014 kharif season pulse crop declines significantly.



	All Pulses	Gram	Arhar	Mung	Masur	Urad
Jan	15.9	22.5	7.9	19.6	18.1	-0.4
Feb	14.0	16.4	11.4	17.8	19.1	3.2
Mar	10.8	7.6	17.1	17.1	20.2	5.5
Apr	10.5	4.5	20.6	19.1	23.0	6.8
May	5.9	-2.2	16.6	18.5	15.8	7.0
Jun	1.6	-9.2	14.2	20.1	15.6	4.6
Jul	-7.4	-19.8	5.1	12.1	11.7	0.8
Aug	-14.7	-27.2	-2.6	3.4	6.4	-5.4
Sep	-13.4	-25.5	-2.8	8.8	6.1	-7.1
Oct	-10.7	-23.9	0.6	14.3	6.0	-2.7
Nov	-10.6	-26.2	3.9	14.5	6.9	3.9
Dec	-7.2	-23.5	9.2	16.9	12.5	5.2

Fig. 5: Wholesale Price Inflation Trend in Pulses (% change in 2013 over 2012)

Trade

India imported about 4 million tonnes of pulses during 2012-13. Although based on current assessment kharif pulses production in 2013-14 has remained nearly the same as in 2012-13, due to a likely increase in *rabi* season pulse production, imports are expected to decline marginally during 2014-15. .

From Fig. 6 it is seen that import of pulses in 2013 has shown a decline in September. Gram imports were the highest in January, but became negligible thereafter as domestic production was at a record level. Dry pea imports are seen to be fluctuating while masur imports increased till July 2013. Overall, import requirements may be of the order of 3.8 million tonnes in the current year.

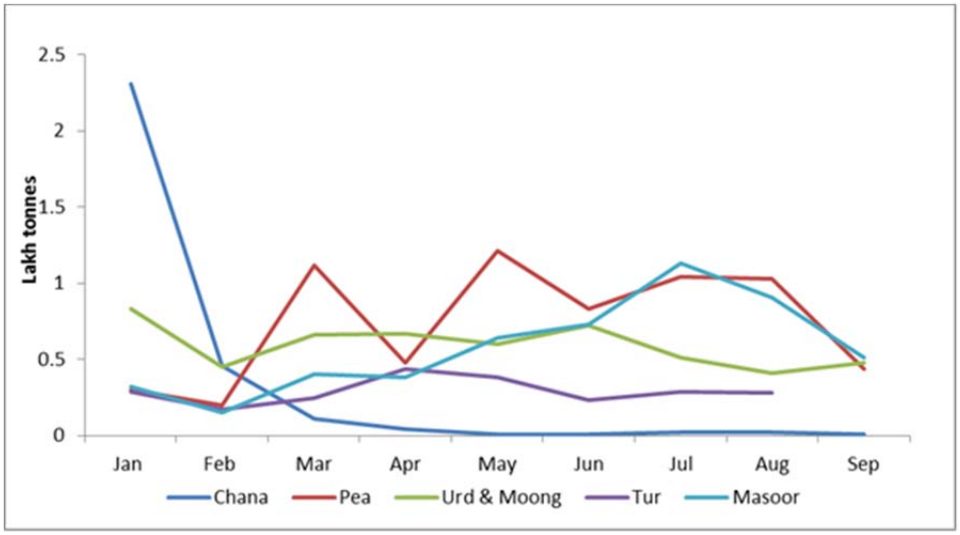


Fig. 6: Month wise Pulse Import during 2013

Despite being world's largest producer of pulses, only small exports of pulses are taking place from India, both because of restrictions on exports and the high domestic demand. The supply- demand balance sheet for pulses is provided in below.

Table 3: Demand and Supply Balance Sheet for Pulses (000 tonnes)

Total pulses	2010-11	2011-12	2012-13	2013-14
Production	18,240	17,090	18,340	19,770
Imports	2,780	3,500	4,010	3,500
Total supply	21,020	20,590	22,350	23,270
Total Export	209	175	200	200
Domestic Use	20,811	20,415	22,150	23,070

Total utilization	21,020	20,590	22,350	23,270
% imports to production	15.2	20.5	21.7	17.8

Pulse production and sustainability

Environmental benefits:

Nitrogen fixation

Nitrogen is the nutrient most commonly deficient in soils around the world, and is therefore the most commonly applied plant nutrient, often in the form of synthetic fertilizer. **Legume crops, including pulses, have a unique role to play in the global nitrogen cycle, as they fix atmospheric nitrogen in soils**. Pulses create a symbiotic association with rhizobia, a soil bacteria, enabling pulses to fix atmospheric nitrogen gas, which can make them self-sufficient in nitrogen, and enable them to grow in almost any soil without fertilizer inputs. Human impacts on the global nitrogen cycle from rapidly increasing fertilizer use and fossil fuel combustion starting in the 20th century have had strong negative effects, such as pollution into waterways and increased N2O emissions.

From 1960 to 2000, nitrogen fertilizer use increased by roughly 800%, with half of that being utilized for wheat, rice, and maize production (Canfield et al, 2010). Synthetic fertilizers provided close to half of all the nutrients received by crops globally during the mid-1990s, demonstrating both a large dependency on synthetic fertilizers, but also inefficient management of nitrogen in global agriculture (Smil, 2002). The IPCC estimates that nitrous oxide emissions contain roughly 300 times the global warming potential of carbon dioxide (CO_2), and application of fertilizer in agricultural production is a significant source of N_2O. Cereal crops such as wheat, rice and maize typically only utilize 40% of fertilizer applied, leading to significant waste and environmental impacts such as eutrophication of coastal waters and creation of hypoxic zones (Canfield et al, 2010). A survey of various field studies of nitrogen fertilizer uptake by rice, corn and wheat shows typical nitrogen efficiency to be less than 50%, with Asian rice averaging as little as 30%. The study also found nitrogen losses along the food chain to be significant, with synthetic fertilizers causing significantly more nitrogen loss due to volatilization, erosion and leaching into water (Smil, 2002).

However, introduction of pulses into crop rotations actively helps fix nitrogen in the soil, thus reducing the fertilizer requirements of the pulse crop itself, as well as the following grain crop. One long-term study (2001 – 2013) on the nitrogen fixation of the pulse crop itself found field pea, lupin or faba bean derived about 70% of nitrogen requirements from atmospheric nitrogen, while an average of 19 kg of nitrogen was fixed per tonne of pulse shoot dry matter. The study covered the geographic range of southern and central New South Wales, Mallee and Wimmera in Victoria, and the high-rainfall zone of south-eastern South Australia (Peoples et al, 2015). Systematic crop rotation based on incorporating pulses/legumes into maize-based systems to reduce synthetic fertilizer use, and optimizing the timing and amounts of fertilizer applied to crops are recognized as the two most important interventions to decrease nitrogen application (Canfield et al, 2010). Biological nitrogen fixation is a crucial alternative source of nitrogen, and can be enhanced along with other integrated nutrient management strategies such as animal manure and other bio solids, and recycling the nutrients contained in crop residues (Lal, 2004).

The higher available nitrogen to subsequent cereal crops is generally assumed to **benefit yields of those cereal crops**, however this is not as well documented as the nitrogen fixation benefits. Findings in south-eastern Australia indicate strong evidence that the inclusion of legumes in cropping sequences results in higher available soil nitrogen for subsequent crops, with an additional 40 to 90 kg N/ha in the first year and 20 to 35 kg N/ha for the second year, as compared to continuous cereal sequences that do not include pulses (Peoples et al, 2015). Apart from the effects of additional fixed N that legume crops bring into systems, there are almost always beneficial yield effects from crop rotations with legumes. These positive effects on yield are probably related to disruption of the buildup of disease and pests that occurs when a particular crop is grown year after year, although this phenomenon is not yet well understood. Increases in grain yield in subsequent cereal crops have been documented in the Northern Great Plains of North America. Evidence in a Mediterranean environment demonstrated that vetch, faba bean and chickpea all resulted in significant yield surpluses and provided nitrogen credit to the subsequent unfertilized wheat crop, though vetch outperformed the other (better researched) pulses (Dalias, 2015). Experiences in Australia show increased yield and protein content in cereal and oilseed crops that are planted following pulse crops.

The wide variations in the amount of nitrogen fixation that pulses can provide depends on the amount of biomass produced by the pulse crop (often varying with water, soil quality and non-N nutrient availability), whether the harvest removes a significant amount of the biomass, and the effectiveness of the legume-rhizobium symbiosis in fixing nitrogen. Planting a legume into soils already having moderate to high levels of soil nitrogen can also depress biological nitrogen fixation.

Nuances and differences in successive cereal crops must be noted. Findings in Australia comparing legume and fertilizer nitrogen indicate that recovery of legume nitrogen by a following cereal crop tends to be lower than top-dressed fertilizer (a difference of 20% between high and low ranges), but is not too dissimilar from fertilizer applied at sowing. This is due to slower release of mineral nitrogen from legume and pulse crop residues as they decompose. However, losses of nitrogen from the system are found to be usually lower from legume sources than from fertilizer, indicating the contribution of legumes to the maintenance of the long-term organic fertility of soils (Peoples et al, 2015).

The successive planting of different crops on the same plot of land, through crop rotations, helps soil fertility, the transfer of nutrients from one crop to the next, and helps to control weeds, pests and diseases. **Crop rotations have been practiced by farmers for thousands of years, yet maximizing the environmental, social and economic benefits of crop rotations is an ever-evolving science that must address many factors at the cropping system level**. The replenishment of nitrogen through the use of green manure, in sequence with cereals, is a common form of crop rotation. Including pulses in cropping systems has high relevance for improving the overall use efficiency of available nitrogen at the farm system level rather than at just the crop level. Rather than emphasizing individual elements of a cropping system, a focus on overall growing conditions, the crop mix, and the sequence of crop rotations is central to achieving both sustainability and productivity objectives, such as increasing nitrogen fixation through improved rhizobia-host plant symbiosis (van Kessel and Hartley, 2000).

Conservation tillage

Changes in tillage practices have been an important part of shifts from conventional cropping systems, based on grain production, to more diversified crop rotations utilizing pulses or oilseeds. Conventional plow-based farming developed largely as a means for farmers to control weeds in field-crop systems. Conventional tillage practices leave soil vulnerable to water and wind erosion, increases agricultural runoff, degrades soil productivity and releases GHG emissions both from soil disturbance and fossil fuel use. Conventional tillage in the US, Canada and Australia led to "dust bowl" storms due to wind erosion, and the loss of soil and farmland spurred policy makers and farmers to find solutions. No-till, or direct seeding under a mulch layer from the previous crop, is the most important technology in conservation agriculture and reverses this process by implementing a package of practices, including a) minimum mechanical soil disturbance, b) permanent organic soil cover, c) diversification of crop species grown in sequences and/or associations (FAO, 2013). Importantly, implementing conservation tillage practices has often involved introduction of pulses and oilseeds into grain-based crop rotations. While increased use of herbicides, such as glyphosate, have been utilized to address weed abundance under reduced or no-tillage, this appears to be moderated after a period of transition to conservation tillage. Van Kessel and Hartley (2000) identified a range of studies that demonstrate the nitrogen fixation benefits of conservation or no-tillage, with pulse and oilseed bean nodulation improving after multiple years of no-till and nitrogen fixation rates increasing (moderated by changes in rainfall patterns) (Van Kessel and Hartley, 2000).

Productivity improvements over area expansion

An important goal in the sustainable use of land worldwide is to increase productivity on available croplands, while restricting agricultural expansion, which often occurs at the expense of forests and wetlands. Nine billion people will inhabit the planet by 2050. To avoid crop expansion and just meet projected 2050 crop needs by increasing production, it is predicted that crop yields would need to increase by an estimated 32% more from 2006 to 2050 than they did from 1962 to 2006 during the height of the 'green revolution (Searchinger et al, 2013).' However, reaching such increases in yields is highly unlikely. Pulses have a significant role to play in 'sustainable intensification,' yet, in developing countries, production increases have come primarily from expansion of cropping areas. The yield growth of pulses between 1980 and 2004 in developed countries was 2%

per annum, while in developing countries, it languished at about 0.4% per annum (Nedumaran et al, 2015)

This large yield gap between developing countries and developed countries is of concern, and cannot be addressed by improved pulse crop genetics alone, but rather requires a range of interventions, some of which are further explored in the Africa case

Reduced greenhouse gas emissions

The role of pulse crops in mitigating greenhouse gas emissions in agriculture production can be significant, and this is explored further in the Saskatchewan case study below. The primary reason for the benefits from pulses in lowering GHG emissions is due to lower fertilizer requirements, particularly given the large amount of energy used in fertilizer production. Up to 70% of the non-renewable energy used in Western Canadian cropping systems is due to the use of fertilizers, particularly nitrogen, and the inclusion of pulses in cropping systems reduces the need for fertilizer inputs. Pulses supply their own nitrogen and contribute nitrogen to succeeding crops (Lemke et al, 2007)

Pulses and livestock feed diversification

Integration of legumes into livestock production systems has been shown to deliver multiple benefits, such as increased nitrogen supply while also increasing meat production. Globally, meat demand is expected to increase by 200 million tonnes per annum by 2050, with corresponding demand for livestock feed (Alexandratos and Bruinsma, 2013). In the northern Great Plains of the US and Canada, field pea has been promoted as a means to boost protein and energy in cattle feed. Field pea grain has been found to be highly digestible to cattle, but the starch fermentation and ruminal protein degradation rates are slower than for other common feeds. Field pea has been shown to increase dry matter intake by cows when included in the livestock feed ration, and also produces benefits when used as a binding agent for pelleting formula feeds .

Social benefits

Nutrition

Without a concerted effort to boost the production of pulses in developing countries, consumption of pulses may stagnate or decline, due to changing consumer preferences, failure to promote production of pulses, and a greater focus on increasing production and self-sufficiency in cereals (Alexandratos and Bruinsma, 2012). Historically, when observed declines in protein-rich pulses were not accompanied by increases in the consumption of livestock products, the result has been deterioration in the overall quality of diets, even if per capita dietary energy increased.

Pulses have declined in consumption levels globally and in particular among developing countries, perhaps best illustrated by China's significant decrease in consumption, from 30 g per capita per day in 1963, to only 3 g per capita by 2003 (Kearney, 2010). Over the last decade, developing countries, particularly in large Asian economies, have seen steady population growth, rising per capita incomes and continuous urbanization, which has been accompanied by increased protein intake relative to the traditional starches. The OECD/FAO Agricultural Outlook to 2024 indicates stagnant growth in food consumption in developed countries, but significant increases in developing countries, reflecting this increase in protein intake in developing countries. At the global level, total caloric intake is expected to rise, but with regional differences. Cereals will remain the most consumed agricultural product, with consumption expected to increase by almost 390 Mt by 2024, most of which is coarse grains. The largest expected growth in coarse gain consumption will come from demand for feed, accounting for 70% of the growth in consumption. Global meat consumption is expected to grow 1.4% per year, resulting in additional consumption of 51 Mt of meat by 2024 (OECD-FAO, 2015).

India provides a counterpoint to China, as pulses there provide an increasing source of protein, now accounting for almost 13% of overall protein intake (OECD-FAO, 2014). Pulses are an important contribution to a vegetarian diet, given their protein content. India is the largest pulse producer and consumer, and the country grows the largest varieties of pulses in the world, accounting for about 32% of the area and 26% of world production. Indian pulse crops include chickpea, pigeonpea, urd bean, mung bean, lentil and field pea, and production reached a record level of 18.4 Mt in 2012-13, up from 15 Mt in 2007- 08. Pulse crop yields have increased from 0.63 t/ha in 2007-08 to 0.79 t/ha in 2012-13, and annual yield growth is expected to outpace growth in production area, indicating better production efficiency. However, the average productivity of pulses in India still remains below the global average. It is expected that Indian production will not keep pace with demand and imports are anticipated to grow to 5.1 Mt by 2023 (OECD-FAO, 2014).

Fairly recent changes in the global human diet favouring more energy-dense foods rich in total and saturated fats are increasing rates of obesity, diet-related diseases such as diabetes, coronary heart disease and cancer. Public health and nutrition efforts seeking to promote healthier and more sustainable food production and consumption, must ensure a sufficient supply of staples and of micronutrient-rich foods without encouraging excessive consumption of energy-dense, nutrient-poor foods. Pulses and legumes are an important contributor of micronutrient-rich intake, along with fruits and vegetables (Kearney, 2010). Eighty-four percent of the protein in common bean is readily absorbed after consumption, and 94% of the protein from cowpea is available.

Pulses have a role to play in combating cardiovascular disease and increasing healthy nutrition. Worldwide, cardiovascular diseases are now the leading cause of death, and in the United States, is attributed to 1/3 of all deaths. While there is increasing awareness of this risk, and the role of balanced diets to decrease the risk, less than 1/3 of Americans consumes the 3 cups of legumes recommended per week by the Dietary Guidelines for Americans (Bazzano et al, 2011). A meta-analysis of ten randomized controlled trials from 5 countries sought to quantify the impact that consumption of non-soy legumes (navy, pinto, kidney, garbanzo and lima beans and peas such as split green peas or lentils) has on total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), very low-density lipoprotein (VLDL), and triglycerides. Findings indicate the **non-soy legume diet had a significant beneficial effect on serum cholesterol levels, thus reducing cardiovascular disease risk**. Both total and LDL cholesterol decreased, while HDL cholesterol did not change significantly, when non-soy legumes were supplemented. Further, findings indicate that the non-soy legume diet allowed for higher intakes of dietary total and soluble fiber (which lowers risk of coronary heart disease) and contained phytosterols, a component of plant cell membranes, which reduces blood cholesterol levels (*ibid*). The anti- inflammatory effects of beans and their contribution to the intestinal microbiome in the gut is increasingly being understood, particularly in among children in Malawi where findings indicate cowpea and common bean can reduce environmental enteric dysfunction (Manary, 2015).

Nitrogen and protein in global diets

More dietary protein will be needed to eliminate disparities in diets between developed and developing economies. However, the nitrogen budget in global food and feed demonstrates **the importance of nitrogen-rich and protein-rich plant foods**. About 70% of nitrogen in harvested food crops become available (after processing and losses) for human consumption, whereas meat and dairy production use large amounts of nitrogen. Nearly 7 kg of feed nitrogen is needed to produce 1 kg of edible nitrogen in meat, eggs, and dairy products. Thus, finding solutions to more efficient production of animal foods and damping the projected upward trend line of animal based foods is crucial to supply adequate nutrition to the world's growing population without any massive increases of nitrogen inputs (Smil, 2002).

In Canada, the US, and Europe, researchers, ingredient companies and food manufacturers are investigating **increased production and use of pulse protein fractions in manufactured food products,** in order to boost the nutritional quality of foods, and dietary fibre and starch, which can be used for food fortification and texture enhancement. In these processes, parts are derived from the whole seed, such as a split seed, hull or fibre, down to isolated starch and protein factions. These products are promoted as plant-based, sustainable, non-genetically modified and gluten-free. Companies such as Ingredion, AGT Foods, Burcon, Cosucra, and Nutri-Pea and others are creating fraction products, and finding ways to incorporate them into manufactured food products. Researchers note that wet fractionation uses large amounts of water and energy, and the functionality of the protein is compromised during processing. Dry fractionation is found to be more water and energy efficient, and retains functionality of the pulse protein.

Efforts to manufacture meat-like protein products is improving, with a recent soy-based meat analogue product being produced, with a thickness of 30 mm (Krintiras et al, 2016) . Efforts are underway to further identify how pea protein and other vegetable fibers can be used for this purpose.

Balancing livestock production and food security through pulses

Livestock production benefits without food security conflicts are demonstrated via the integration of herbaceous legumes into the maize and upland rice systems in West Timor, Indonesia. After six years of participatory research, findings indicate significant benefits for local farmers. Farmers usually rely on low-quality native forages, sometimes supplemented, to feed their livestock. High rainfall levels in the monsoon season and climate variability provides risks that often result in feed demands outstripping supply and low rates of production, with up to 60% of the weight gained by livestock during the wet season lost during the late dry and early wet seasons. Herbaceous legumes were added either in annual rotation with a cereal or after wet- season cereal production has been completed, when land is traditionally left fallow. As cowpea, peanut, and mung bean are already occasionally intercropped with maize in the wet season, researchers chose to promote herbaceous legumes as a green manure or in rotation, so legumes would not further compete with the cereal crops for nutrients and thereby produce less forage. Research outcomes indicate that a) it is possible to add an additional crop into a traditional farming system without affecting existing food security, b) that feeding forage legumes to cattle during the late dry or early wet season resulted in increases in livestock weight, and c) that nitrogen provided by legumes improved maize production in subsequent crops. Critical to the success of integrating herbaceous legumes into an annual crop cycle was the recognition that water remaining in the soil as the main wet-season cereal crop matures is a resource that can be available for the subsequent dry-season production of herbaceous legumes, which is a period in which food crops are not traditionally grown (Nulik et al, 2013).

Gender

Gender aspects of pulse production are particularly important in contexts where women can be involved in various stages of production and throughout the value chain.

Economic benefits

Farmers in grain and oilseed production have found economic benefits from lower input costs and increased profits by including a pulse crop in their rotation. These benefits accrue mainly through enhancing the efficiency of nitrogen fertilizer use, reducing tillage and, in some cases reducing pesticide use. **Reduced and altered tillage practices reduce reliance on fossil fuels and lowers overall fuel bills**. No-till systems with pulses provide a basis for sustainable agricultural intensification, including integrated crop approaches. It is estimated that farmers save between 30-40% of time, labour and fossil fuels using no-till, compared to conventional tillage. Better nitrogen management requires less fertilizer inputs. There are variations, of course, in the economic returns experienced in different geographies and farm-types, and these are explored further in the case studies. Farmers likely also see the **long-term economic benefits (and avoided costs) of less soil, air and water degradation by adopting no-till practices and including legumes in their operations**.

India, which is the largest consumer of pulses globally. India sought to increase pulse production by 2 million tonnes by the end of the Eleventh Five Year Development Plan (2011-12), through implementation of the

National Food Security Mission for Pulse Crops (NFSM). However, economic gains from pulse production could be far greater in India, and import tariffs, minimum price supports, and government support has largely underserved the needs of India producing enough pulses to meet domestic demand and diversify farm incomes.

Investments in pulse crop research is shown to have significant economic benefit. The CGIAR Research Program on Grain Legumes, a global alliance coordinating efforts across four CGIAR centres, estimated in 2012 that the net present value of gross benefits of its legume research and extension is estimated at US$ 4.5 billion, equivalent to US$ 535 million per year. Based on proposed activities to be undertaken by this CGIAR program, between 2014–2020, legume research was also projected to contribute to food security through increased availability of food (over 8 million tons), nutrition security from more availability of protein, and environmental benefits through biological nitrogen fixation (a fertilizer cost saving of US$ 418 million) . The CGIAR estimated that over 50% of the projected economic benefits of legume research and extension would accrue in South and South-East Asia and Sub-Saharan Africa, where most of the world's poorest communities are located (CGIAR, 2012).

Adding pulses into livestock diets also has economic benefit, but appears dependent on market pricing and labour use efficiencies. Findings in Western China indicate that livestock forage system intensification by incorporating a forage crop into grain-cropping systems increased average profits without increasing downside risks such as negative profit, crop failure, or livestock mortality. Forage vetch was the leguminous pulse crop, but forage oats and grain soybean were also incorporated. In contrast, replacing a grain crop with a forage crop in grain-cropping systems had a negative effect on profits, downside risk, and labour-use efficiency. Trade-offs between labour-use efficiency and profit were observed as forage intensification increased labour demands, however these effects were context specific (Komarek et al, 2014).

The Rot in Indian Agriculture Policies and Economic challenges for Pulses in India

Every aspect of Indian economic policies is influenced by all-pervading government control. Many times, they are also subject to massive leakages due to inefficiencies and corruption (for example, bogus ration cards, rotting grains and corrupt procurement in the public distribution system). The poor state of industrial development, inability to increase domestic defence production in spite of massive imports, diversion of government revenues from taxes on minerals, mismatch between demand for agricultural products and their production, and so on, are some examples. India has massive unemployment and underemployment. More are seeking fresh employment each year, consumption levels are low, and there are many poor people. Yet, growth in production of physical goods from agriculture and industry has, in five years since 2011, been modest. At constant prices, agriculture grew annually from 2011 in per cent at 1.5, 4.2, -9.2 and 1.1. Over these years, industry grew in per cent at 3.6, 5.0, 5.9, and 7.3; manufacturing at 6.0, 5.6, 5.5 and 9.5. There is heavy pressure of population on land. The average size of land holding was 1.41 hectares in 1995-96 and 1.15 in 2010-11.

India has more arable land than China. Indeed it has the second-most arable land in the world. But it has very low productivity of crops per acre. When one takes paddy, as one example, and on comparing with China, India remains far behind. This is so for other crops as well and as compared to most Southeast Asian countries.

A good reason for the low productivity is the growing fragmentation of holdings and their decline in size. The high population pressure on small land holdings is on account of high rural poverty. Alleviation requires consolidation of land holdings by leasing, urbanization and the acquisition of rural lands for the purpose with adequate compensation. This will also reduce this pressure. Consumption habits are changing at all levels. Rice consumption per person per month in rural India was estimated at 5.98 kilogramme in 2011-12 compared to 6.38 kg in 2004-05 - a fall of 0.4 kg in seven years. In urban India, the fall in rice consumption between these two periods was 0.2 kg per person per month – from 4.71 kg to 4.49 kg per capita. A high proportion was taken at subsidized prices from the public distribution system. Per capita consumption of wheat in 2011-12 showed a slight rise since 2004-05 of about 0.1 kg per person per month in rural areas and a fall of 0.35 kg in urban areas. As with rice, the share of PDS purchase in wheat consumption has increased considerably, from 824 grammes to 901 gm in the urban sector. At the same time, and in contrast, 69 gm in the rural sector and 57 gm in the urban sector were contributed by split gram, whole gram, pea and *besan* bought at rising market prices. The four pulses - *arhar*, *moong*, *masur* and *urd* - also rose. So did consumption of vegetables, eggs and fruits. All these have seen rising prices and no price support to consumers.

Minimum support prices for cereals are increased almost every year and have been the same as procurement prices. But retail prices were not raised similarly. There is also government interference in the agricultural markets which cause the farmer to lose the margins made by middlemen. India has stimulated the production of cereals when the demand was dropping, while growing for other nonsubsidized items. Rural households bought the cheap PDS grains and sold their own produce for government stocks, which are at unsustainably high levels without adequate storage. They might as well have been given free to the malnourished rural poor.

Productivity remained low because of falling land holdings. Improved seeds were not easily available. Genetic modification of food grains was prevented by environmentalists with no evidence of ill-effects. (Research has shown no ill-effects on humans; in some cases, there might be resistance to plant resistance.)

Fertilizers are subsidized, benefiting manufacturers and big farmers. Subsidies are relatively more for urea, leading to a mismatch in fertilizer use and inadequate productivity. Water availability has been shrinking as lakes and rivers become polluted and groundwater levels are used excessively.

Per-capita availability of fresh water has declined sharply, from 3,000 cubic metres to 1,123 cubic metres over the past 50 years *versus* the global average of 6,000 cubic metres. India needs to make judicious use of surface water and groundwater. Dams on rivers have robbed some of them of their usual water flow, while diverting the course of others. Urban effluents have also destroyed the portability of river water. Fifty five per cent of India's total water supply is now groundwater. This has reduced levels across much of India. Growing water-intensive crops and using techniques like flooding for paddy have further depleted groundwater. Over 60 per cent of irrigation comes from groundwater. Nearly 30 per cent of urban water supply and 70 per cent of rural water supply come from groundwater. We need a rational water policy and less populism. Massive subsidies on equipment and electricity required to mine groundwater have accentuated its use to the financial detriment of the power sector. Free or heavily subsidized flat rate electricity tariffs helped bring the Green Revolution. They have now become the norm. The result is indiscriminate use of groundwater. Each of the issues mentioned is the result of government policies or their absence. Land legislation encourages fragmentation of holdings. There is little encouragement for leasing. Land acquisition for urban areas and for factories has been a corrupt business, and there is little incentive for many farmers to give up their land and move away. Government procurement policies and the public distribution system have stimulated rising production of rice and wheat. Little has been done to help production, storage and marketing of other items like vegetables, pulses, fruits and eggs (such as cold storages, improved varieties, and so on). There is little sign of a rational water policy: indeed, it is the opposite. Electricity tariffs encourage a rise in the use of groundwater. There is no policy on groundwater. Neither is there a limit on what water intensive crops can be grown with it. There is no concerted recharging of groundwater. State governments follow irrational water-pricing policies. Cleaning up river and lake water so that it is available to supplement water supply in case of drought is uncommon. Little is being done to spread better agricultural practices and scientific developments that benefit farmers.

Agricultural productivity can be increased even on small holdings, but there is little attempt, except by nongovernmental organizations, to disseminate these practices. In Israel, these have reduced the use of water.

There are vineyards producing good wine in the Negev desert. Groundwater use is not metered in India as it should be. Fertilizer subsidies do not benefit the small farmer. Rational policies, which ensure that subsidies reach the farmer and do not encourage unbalanced use of fertilizers, are urgently needed. Environmental agitations against genetically modified seeds should be countered by scientific evidence so that more productive seeds can be used. Agricultural policies have developed into a messy package. They need a thorough overhaul. Our political masters are unable to even think of it.

India is the largest consumer of pulses, but government subsidies and price controls in the agricultural sector created distortions that affected domestic production. Government subsidies for fertilizer and water promoted grains and oilseeds rather than the mix of support necessary to promote pulses.

Protectionist policies in the 1970s and 1980s were reversed in the 1990s, when government reforms sought to remove import restrictions and lower tariffs on agricultural products. However, with the exception of Basmati rice and durum wheat, external trade in all major crops was regulated, and imports of most crops occurred only through government agencies. Pulses were treated differently, with import tariffs on pulses reduced gradually and abolished by 1996. The hope that domestic pulse market liberalization would increase imports did not materialize. Rather, the share of total pulse imports in total merchandise trade declined after market liberalization (Agbola, 2004).

Further, in India, minimum support prices have been established as one of the policy instruments used to improve the economic viability of farming, stablize commodity prices, and enhance food security by diversification into oilseeds, pulses, livestock and fish. However, **minimum support prices for pulses have not demonstrated the same results as those for rice**. Prices for pulses were increased between 2008-09, at a rate higher than that for food grains, but that did not translate into larger areas planted under pulses, and this is attributed to the risks associated with pulse cultivation. In comparison, paddy cultivation does not carry such risks, and farmers are assured of procurement by government agencies, whereas this is not the case for pulses (OECD-FAO, 2014).